TEXT-BOOK

OF

INDUCTIVE LOGIC

WITH COPIOUS EXAMPLES AND QUESTIONS

BY

JADUNATH SINHA, M.A., PH.D.,
Premchand Roychand Scholar,

PROFESSOR OF PHILOSOPHY, MEERUT COLLEGE, AUTHOR OF *Indian Psychology: Perception*, *Indian Realism*, AND OTHER BOOKS; MEMBER OF FACULTY OF ARTS, AGRA UNIVERSITY, MEMBER OF BOARD OF STUDIES IN PHILOSOPHY, AGRA UNIVERSITY; EXAMINER, EIGHT UNIVERSITIES IN INDIA.

First Edition

MEERUT

1941

Published by the Author,
Meerut College, Meerut.

Sole Agents (Bengal):
THE BOOK COMPANY Ltd.,
College Square, CALCUTTA.

Sole Agents (U. P.):
JAI PRAKASH NATH & Co.,
Booksellers, MEERUT.

Printed by Ibadullah Khan
at the
Station Press, Meerut.

PREFACE

This book is an elementary Textbook. It has no pretension to originality. It attempts to present the problems of Inductive Logic in such a manner that the students of the Intermediate classes of the Indian Universities may easily master the subject. It treats of the main problems of Inductive Logic in a simple language. It explains all topics by means of copious examples from sciences and every-day experience. Profuse illustrations and simple language are the special features of this book. It steers a middle course between an elementary manual and an advanced textbook. It does not deal with the controversial questions in detail. Nor does it avoid them altogether. Typical questions have been appended to each chapter for revision. The students are strongly advised to solve them after finishing a chapter. Special attention of the students is drawn to the chapters on the Experimental Methods and the Analysis of Inductive Arguments. Fallacies have been treated in immediate connection with those parts of logical doctrine against which they offend. They have also been summarised in a separate chapter.

I acknowledge my indebtedness to the authors whose works I have referred to in course of writing the book. My special obligations are due to J. S. Mill, Bain, Carveth Read, Welton, Fowler and Creighton whose works have proved very helpful to me.

MEERUT COLLGE,
MEERUT,
August, 1941.

JADUNATH SINHA.

CONTENTS

PAGE

CHAPTER I

THE PROBLEM OF INDUCTION

CHAPTER II

DIFFERENT KINDS OF INDUCTION

CHAPTER III

THE FORMAL GROUNDS OR POSTULATES OF INDUCTION

PAGE

CHAPTER VIII

ANALOGY

CHAPTER IX

THEORY OF PROBABILITY: ELIMINATION OF CHANCE

CHAPTER X

EXPLANATION

PAGE

CHAPTER XI

THE LAWS OF NATURE

CHAPTER XII

CLASSIFICATION

CHAPTER XIII

DEFINITION

CHAPTER XIV

NOMENCLATURE AND TERMINOLOGY

SYLLABUS

Calcutta University

Material Logic. Nature of Truth. Knowledge and Reality. Sources of Knowledge: Perception, Inference, Authority, Necessary Truth. Generalisation and the General Idea. Science. Laws of Nature. Uniformity of Nature. The grounds and conditions of Inductive Inference. Causality. Origin of belief in universal causation. Energy and Conservation. Causes and Conditions. Plurality of Causes. Composition of Causes, and Intermixture of Effects. Discovery and Proof. Hypotheses: their uses and conditions. Theory, Verification. Observation and Experiment and their uses. The Experimental Methods, and their uses, with examples of their application. Fallacies of Observation.

Nature, place and use of the Inductive Method. Perfect and Imperfect. Complete and Incomplete Induction. Inference from Analogy. Inference from Simple Enumeration. Inductive Probability; Chance and its Elimination. Scientific Induction. Processes simulating Induction. Fallacies in Inductive Reasoning.

Classification, Natural and Artificial, and its conditions. Relation of Classification to Division. Definition and its material conditions. Description. Type. Errors in Classification and Definition. Terminology and Nomenclature. Nature, place and use of the Deductive Method. Relation of Induction and Deduction. Nature, function and value of the syllogism. Inductive and Deductive Sciences. The actual Method of Scientific Progress. Demonstration. The World as a system of Law. Explanation and its limits.

Patna University

Material Logic. Knowledge, Reality and Truth. Different Sources of Knowledge. Necessary Truth.

The Postulates of Induction. Uniformity of Nature and Causation. Energy and Conservation. Causes and Conditions. Plurality of Causes and Intermixture of Effects. Composition of

Perfect and Imperfect Induction. Imperfect Induction in Simple Enumeration. Analogy. Assumptions of Scientific Induction. The Law of Causation. Uniformity of Nature. Causes and Conditions. Plurality of Causes. Intermixture of Effects. Discovery and Proof as the object of Induction.

The Inductive Methods.

The Deductive Method of Investigation. The value and function of a Hypothesis. Conditions of validity of a Hypothesis. Crucial Instances. Empirical Generalisation and Laws of Nature. Explanation and its various forms.

Fallacies of Induction.

The Punjab University

I.—Definition, scope and use of Induction. Observation and Experiment. Regulative Principles of Observation and Experiment. Advantages of Experiment over Observation. Classification and Nomenclature. Generalisation.

II.—Perfect and Imperfect Induction. The assumptions of Scientific Induction. The Law of Causation. Uniformity of Nature. Causes and Conditions. Plurality of Causes. Intermixture of Effects. Discovery and Proof as the object of Induction.

III.—The Inductive Methods. Imperfect Inductions. Simple Enumeration. Analogy.

The Deductive Method of Investigation. The value and function of an Hypothesis. Conditions of Validity of an Hypothesis. Crucial Instances. Empirical Generalisations and Laws of nature. Explanation and its various forms.

IV.—Fallacies of Induction.

Madras University

Inductive Inference. Postulates of Induction. Induction and Analogy. The Relation of Deduction to Induction.

Theory of Scientific Method. Observation and Experiment. Hypothesis. Empirical and Causal Laws. Forms of Explanation. Elimination of Chance. Scientific Definition and Classification. Nomenclature and Terminology. Fallacies.

Bombay University

Probable Reasoning. Definition. Classification and Division. The nature and presupposition of Induction. Empirical Laws. Inductive Methods. Observation and Experiment. Explanation. Hypothesis. Analogy. Fallacies—Inductive.

Ceylon (London Matriculation)

Inductive reasoning in its various forms. Observation and experiment: Canons of Scientific Induction; Combination of induction and deduction; hypothesis and explanation. Fallacies.

CHAPTER I

THE PROBLEM OF INDUCTION

1. The Nature of Inference.

Inference is mediate knowledge. It is distinguished from perception or immediate knowledge. It is derived through the medium of some other knowledge. It is the mental process by which we pass from some known fact or facts to some other unknown fact. "Inference consists in asserting as fact or truth, on the ground of certain given facts or truths, something which is not included in those data. We have not got inference unless the conclusion (*i*) is necessary from the premises, and (*ii*) goes beyond the premises."[1] In an inference the conclusion *follows* from the premises, and yet it goes *beyond* them. The conclusion must contain an element of *novelty*. It must be new to the data or premises. And yet it must be *necessary*, *i. e.* it must follow from the premises. Bosanquet rightly points out that *necessity* and *novelty* are the characteristics of inference. In inference we pass from the *known* to the *unknown*. In it we reason from the data or known truths to a new truth. What was implicit in the premises becomes explicit in the conclusion. The task of inference is to draw out the implications of the premises. It shows that a new fact or truth necessarily follows from some other known fact or facts.

1 Bosanquet : *Essentials of Logic*, p. 137.

2. The Unity of Nature is the Basis of Inference.

Inference is the process of reasoning from some known fact or facts to some other unknown fact. "Inference requires (1) that certain data or premises should be accepted as already known; and (2 it implies an insight into the necessary connection of some new fact or set of facts with what we already know. We are said to infer whenever we find the ground for the existence of one fact in the nature of another fact."[1]

But how are we justified in passing from one known fact to another different from it? How can we pass from the known to the unknown? We can do so only because they are interconnected parts of a system, which are necessarily related to one another. We can infer one truth from another because they are related to one another as parts of a system called the Unity of Truth. We can infer one fact from another because they are related to one another as parts of a system called the Unity of Nature or Reality. All inference is based on the assumption that Nature or Reality is a system. If it were an aggregate of unconnected parts, no inference would be possible. All inference is based on the assumption that Reality is a system of inter-related parts; we can infer from the whole to the parts, or from the parts to the whole, or from one part to another within the whole, because they form a coherent system. "All inference takes place within a system, where the parts are so held together by a common nature that you can judge from

1 Creighton: *An Introductory Logic*, 1932, pp. 436-37.

some of them what the nature of the others must be. Suppose you were given the leaf of a plant. If you had some systematic botanical knowledge it might be possible to infer the species of plant to which the leaf belonged. That is, from the nature of a part, the nature of the whole to which it belongs could be determined. The part represents the whole—in some sense contains it implicitly. ...If each thing were known by itself, if the parts of our knowledge did not fall together into systems where each part to some extent determines the nature of the other parts, no inference would be possible".[1] The rational basis of all inference is the assumption that the Reality is a coherent system.

3. Deduction and Induction.

Inference shows how particular facts are connected together into a coherent system or whole. Both deduction and induction realize this end. "Deduction begins with a given whole or system and infers from it the character of its parts or elements. Induction begins with individuals, particulars, elements, and tries to show the nature of the whole or system which they constitute, the law governing their inter-relationships."[2]

Deduction passes from the given whole to the parts. Induction passes from the parts to the whole. In deduction a general law or principle known or assumed to be true is applied to a particular case. Deduction shows what are the results of the application of a general law or principle to particular facts. It proceeds from a general

1 *Ibid*, pp. 440-41.

2 Latta and Macbeath : *The Elements of Logic*, 1929, p, 265.

law to its consequences in special instances. It passes from a general law to particular facts. For instance:—

All men are mortal ;
Socrates is a man :
∴ Socrates is mortal.

Here we start with a general law about mankind and apply it to a particular individual. Socrates is known to be mortal because as a man he falls under the general law that all men are mortal.

Sometimes in deductive inference we proceed from a higher law to a lower law or from a law of higher generality to a law of lower generality For instance:—

All animals are mortal ;
All men are animals :
∴ All men are mortal.

Here we start with a higher law and proceed to a lower law. All men are known to be mortal because as animals they fall under the general law that all animals are mortal. Therefore, deductive inference proceeds from a general law to particular facts, or from a higher law to a lower law. Deduction proceeds from the general to the particular, or from the more general to the less general. It always proceeds from the whole to the parts.

Induction, on the other hand, proceeds from the parts to the whole. It proceeds from particular facts to a general law. In induction we start with particular facts and try to discover the general law which unites them. Inductive inference proceeds from the particular to the universal. For instançe, we observe that Rama is mortal, Mohan is

mortal, John is mortal, Abdul is mortal, establish a causal connection between the essential nature of men and mortality, and infer that all men are mortal. "Inductive inference is a process of reading the general law out of particular facts. It is an insight into the nature of the whole or system, based upon a careful examination of the parts".[1]

Induction and deduction are not two *kinds* of reasoning which are quite distinct and independent of each other. They are rather two *aspects* of the process of inference, which are involved in each other. Both exhibit the essential nature of inference. Both show how particular facts or elements are connected together into a system or whole. They differ in their starting point. Deduction starts with the known general law or the system within which particulars fall, and argues from this the nature of the parts and their relations to one another. Deduction shows us the way in which a general law runs through a group of particular facts and reduces them to a coherent system. Induction starts with particular facts and reads a general law out of them, which connects them with one another. Induction gives us an insight into the connection among particular phenomena observed, and the nature of the general law which connects them with one another. We not only obtain a general law through inductive inference but also a perception of its concrete application to particular phenomena. Hence deduction and induction are not two different *kinds* of inference. Inference is the mental process by which we know how phenomena are necessarily connected according to some general principle.

1 *Ibid*, p. 144.

In order to know this, we start with the knowledge we already possess. When we know the general law of connection, and try to discover the nature of some particular fact, we have deductive inference. But when we start with particular facts of sense perception, and try to discover the general law of their connection, we have inductive inference. "But from whatever point we set out, and whatever may be the immediate object of the inference, the result is always the same—an insight into the necessary connection of facts according to some general principle."[1] Thus deduction and induction are two aspects of inference, which are constantly employed together as supplementing each other in explaining the world. But they are studied separately for the sake of convenience.

4. The Problem of Induction: Transition from Deduction to Induction.

Deduction is inference from the whole to the parts. It proceeds from an explicit universal or system to the particular cases which fall under it. It starts with a general law or principle and applies it to a particular fact. It infers the nature of a particular fact in accordance with a known general law. In deductive inference the general law is assumed to be true; it simply enquires whether the conclusion necessarily follows from the premises; it does not question the truth of the data or premises. The problem of *Induction* is how we are able to derive general laws from experience. How do we derive general laws

1 *Ibid*, pp. 446—47.

from particular phenomena observed? This is the problem of Induction.

What is the necessity of passing from deduction to Induction? Deduction is concerned with *formal truth*; in deduction the premises are taken for granted; their material truth is never called in question. Syllogism is an important kind of deductive inference. In syllogism we are not concerned with the material truth of the conclusion. Here we have simply to make sure that the formal rules of syllogism have not been violated. But mere formal truth or self-consistency cannot satisfy our intellectual curiosity.

Let us take the following syllogism :—

All men are mortal;

Mohan is a man :

∴ Mohan is mortal.

How are we to determine the *material validity* of the conclusion of the syllogism? The conclusion of a syllogism is materially true if the premises are materially true. But in deduction we never question the material truth of the premises. A syllogism must have a universal premise, because two particular premises yield no conclusion. At least one of the premises must be universal. The material truth of a particular premise may be ascertained by an appeal to experience. For instance, we may know that 'Mohan is a man' by perception. But how can we ascertain the material truth of the universal premise without which a syllogism is not possible? We cannot determine it by observation. Experience gives us knowledge of individual things and their qualities. It cannot give us knowledge of universal truths. We cannot

possibly observe *all* men past, present, and future. So the universal truth must be known by inference. But is it known by deduction or induction? "In same cases this universal premise may itself be deduced syllogistically from another syllogism, but there must be an end to this process at some stage. We must in the end get universals which are not syllogistically established."[1] Let us take the above example. We may prove its major premise by the following prosyllogism :—

All animals are mortal ;
All men are animals :
∴ All men are mortal.

How do we get the major premise of this syllogism ?

We may deduce it from another prosyllogism :—

All living beings are mortal ;
All animals are living beings:
∴ All animals are mortal.

The major premise of this syllogism, again, requires another syllogism to prove it. There cannot be an end to this process. Thus it involves infinite regress. We cannot finally determine the material truth of the universal premise of a syllogism by deduction. We must, therefore, derive it from *induction.* We derive general propositions or principles from experience of particular facts. Induction is the process of *generalisation.* It consists in establishing a general proposition on the ground of particular facts observed. Thus induction

1 *The Elements of Logic*, p. 266.

is necessary to guarantee the material validity of deduction. It guarantees the material truth of the universal premise of a syllogism.

5. The Nature of Induction or Inductive Inference.

We have discussed the nature of inductive inference as distinguished from deductive inference. We may mention the following characteristics of inductive inference :—

(1) In induction we proceed from particular facts to general truths or laws, while in deduction we proceed from general laws or truths to their application in particular cases. Induction is the process of reasoning by which we proceed from particular facts observed to the general law which connects them with one another. It enables us to pass from *particular* truths to a *general* truth.

> Gold when heated expands ;
> Silver when heated expands ;
> Copper when heated expands ;
> Iron when heated expands ;
> ∴ All metals when heated expand.

Deduction is the process of reasoning by which we proceed from a general law or principle to a particular instance. It moves from laws to facts. It enables us to pass from the more general to the less general truths, or from the general to the particular truths. For example :—

> All metals when heated expand,
> Gold is a metal :
> ∴ Gold when heated expands.

(2) Inductive inference is concerned with *material truth*, while deductive inference is concerned with *formal truth*. In deduction the premises are taken for granted; we do not question their validity. We simply enquire if the conclusion logically follows from the given premises. If it does not violate any rules of inference, it is taken as valid. But in inductive inference we do not assume the truth of the premises which are particular facts. We must actually observe them and make sure of their material truth. We must gather particular facts which are the data of inductive inference from observation and experiment. And the conclusion of inductive inference also must be materially valid.

(3) In inductive inference there is a hazardous 'leap in the dark' or a passage from the known to the unknown. In induction we proceed from particular facts to a general law,—from *some* to *all*. We observe particular facts and derive a general law from them. In induction we must pass from the observed to the unobserved cases—from the present in time and space to the past, the future and the remote—"to the *future* which has not yet come within observation, to the *past* before observation began, to the *remote* where there has been no access to observe. This is the leap, the hazard of induction, which is necessary to complete the process." (*Bain*). Without this leap, our facts are barren; they teach us what has been; but they cannot teach us what will be in future. "A complete induction, then, is a generalization that shall express what is conjoined everywhere, and at all times, superseding for ever the labour of fresh observation." (*Bain*).

This 'inductive leap' is the very essence of inductive inference according to Mill and Bain. If any inference is lacking in this essential characteristic, it cannot be regarded as an induction. The inductive leap constitutes the essence of a scientific induction.

6. The Characteristics of a Scientific Induction.

The conclusion of inductive inference is called an induction. **A scientific induction is a real universal proposition based on observation of particular facts in reliance upon the Uniformity of Nature and the Law of Causation.** Let us bring out the implications of this definition.

1. An induction is a *proposition* as distinguished from a notion or a term. It is the statement of a general truth. It is an affirmation of concurrence or non-concurrence such as 'all men are mortal', 'no men are perfect', etc. So it must be of the nature of a proposition.

2. An induction is a *universal* proposition. In inductive inference we proceed from particular facts observed to a general law. So the conclusion of inductive inference must be general.

3. An induction is a *real* proposition. A verbal proposition merely analyses the connotation of a term; for example, 'all men are rational.' A real proposition, on the other hand, does not merely analyse the connotation of a term but gives some new information about it: for example, 'all men are martal.' An induction is concerned with *material truth*. So it must be a real proposition. It is a general proposition based on facts.

4. An induction is based on *observation* and *experiment*. Its premises are particular facts. They are not taken for granted but are gathered from observation and experiment. They are forms of perception. They supply the data of inductive inference. Hence they are called the *material conditions* of induction.

5. An induction relies upon the *Uniformity of Nature*. The essence of inductive inference is the passage from the known to the unknown—from the observed facts to the unobserved facts—from 'here and now' to the past, the distant, and the future. And this 'inductive leap' is warranted by our belief in the Uniformity of Nature. We believe that Nature behaves in the same way under similar circumstances—Future resembles the past. And this belief enables us to pass from the known to the unknown. If fire has burnt in the past and burns at present, it will burn in future also. Thus we conclude that 'all fire burns' on the strength of the observation of some particular instances.

6. An induction also relies upon the *Law of Causality*. The inductive leap is justified by the belief in the Uniformity of Nature and the Law of Causation. The Law of Causation states—*every event has a cause.* A scientific induction is based upon the establishment of a causal connection between the ground of inference and the inferred property. For example, a causal connection is established between 'the essential nature of men' and 'mortality', and the general proposition 'All men are mortal' is established on the strength of this causal connection. *The Uniformity of Nature and the Law of*

Causation are the postulates or presuppositions of induction. They are called the *formal conditions* of induction.

7. Grounds or Conditions of Induction.

Every form of reasoning involves two factors, *viz.*, *form* and *matter*. There are certain *forms* or principles according to which we reason and also certain *materials* about which we reason. *Deductive* inference is concerned merely with *formal truth*, while *inductive* inference, with *material* truth. In deductive inference we assume the premises to be true ; we do not question their material validity ; we simply enquire whether any conclusion legitimately follows from the *given* premises without violating the *formal* rules of inference. In inductive inference, on the other hand, we do not assume the material truth of the premises ; we enquire into their material validity and draw the conclusion according to the inductive methods. Thus, the grounds of induction are partly *formal* and partly *material*.

(1) The Material Grounds of Induction.

Observation and experiment are called the *material* grounds of induction because they supply the *data*, *materials*, or *premises* of inductive inference. Induction is based on particular facts. These are the data of induction. They are not taken for granted ; they are gathered from actual experience in the shape of observation and experiment. We observe that 'John is mortal', 'James is mortal,' 'Mohan is mortal,' and conclude that 'all men are mortal.' We perceive particular facts, observe them carefully, experiment with them, and discover the general law of nature which connects them with one another. An

induction is based on observation and experiment which supply its data or premises. They are the *material* grounds of induction.

(2) The Formal Grounds of Induction.

In inductive inference we proceed from particular facts to a general law, from the observed to the unobserved —from *some* to *all*. But what warrants us in passing from *some* facts observed to *all* similar facts? What justifies us in passing from the known to the unknown? It is our belief in the Uniformity of Nature and the Law of Causation. We can pass from the known to the unknown because we believe that Nature acts in the same way under the same circumstances or the same cause produces the same effect under the same conditions. Therefore, the Uniformity of Nature and the Law of Causation are the *formal* grounds of induction. They are the postulates or presuppositions of induction. They are the aspects of the Unity of Nature which may be regarded as the foundation of induction.

8. Uses of Induction.

(1) Induction guarantees the *material truth* of deduction. It supplies the *universal premise* of a syllogism. In a syllogism the premises are taken for granted. It is for induction to prove the material truth of a universal proposition without which a syllogism is not possible.

(2) Logic aims at truth, both formal and material. Deduction can prove only formal truth. Induction can prove *material truth*. Deductive Logic is the Science of Consistency. Inductive Logic is the Science of *Fact*.

(3) Induction enables us to discover the *laws of nature.* In inductive inference we observe particular phenomena of nature and find out the laws of nature which govern them. So it is at the root of scientific discoveries.

(4) Induction reveals the inner *unity* and *harmony* of nature. Induction discovers the laws of nature governing the phenomena of nature. These laws are gradually found to be interconnected with one another. They form a coherent system.

(5) Induction helps us in *organising* our experience. It brings many seemingly unconnected facts under a general law and binds them together. It facilitates our memory of numerous facts. It reduces our knowledge into a system. It guides us in future investigations. The general law established by induction is applied to new concrete cases. It helps us in discovering other laws because Nature is a Unity of interconnected parts.

QUESTIONS

1. Explain clearly the nature of Scientific Induction.

2. Define Induction and describe its aim.

3. Have the inductive and deductive process of reasoning anything in common ? What is common to them ? In what do they differ ?

4. Distinguish between Induction and Deduction, and show that the two processes supplement each other in scientific investigation.

5. Why should we pass from Deduction to Induction ? What is the problem of Induction ?

6. What is an Induction ? What are the characteristics of a valid Induction ? Explain and illustrate them fully.

7. What are the presuppositions of inductive inference ?

8. What are the formal and material grounds of Induction ?

9. "Opium is poisonous ;

The substance in my hand is opium :

∴ The substance in my hand is poisonous."

Explain the nature of the logical process underlying the following :—

(*i*) Your belief in the major premise (induction),

(*ii*) Your belief in the minor premise (observation),

(*iii*) Your belief in the conclusion (syllogistic inference or deduction).

10. "The difference between Deduction and Induction is not one of principle but of starting point." Discuss.

CHAPTER II

DIFFERENT KINDS OF INDUCTION

1. Perfect Induction and Imperfect Induction.

The Scholastic logicians of the middle ages divided induction into two kinds, *viz.*, perfect induction and imperfect induction. An induction is said to be *perfect* when it establishes a universal proposition after an examination of *all* the particular instances coming within its sweep. It is based on complete enumeration of *all* the facts. So it is also called an *Induction by Complete Enumeration.* When I examine each and every student of my class and find him to be intelligent, and then make a general statement that 'all the students of my class are intelligent', the process of inference is called Perfect Induction. When I observe each and every rose in my garden and find it to be red, and then make a general statement that 'all the roses in my garden are red', my reasoning is said to be perfect induction. When I measure each individual in a company and find him to be less than six feet in height, and assert that 'all men in the company are less than six feet', my inference is perfect induction. Perfect Induction is the result of a complete enumeration of particular instances. Jevons says, "An Induction is called Perfect, when all of the possible cases or instances to which the conclusion can refer have been examined and enumerated in the premises."[1] It is called

1 *Elementary Lessons in Logic*, pp. 212-13.

perfect because there is perfect certainty about the conclusion. There is no room for doubt about the truth of the conclusion because it is based upon an exhaustive enumeration of all the particular instances.

Perfect Induction is possible, only when there is a *limited class*—when the whole consists of a limited number of parts which can be examined and enumerated. But when the whole consists of an unlimited number of parts, we cannot count and examine them, and, consequently, cannot arrive at a perfect induction.

The Scholastic logicians regard an Induction as *imperfect*, when it is based upon an examination of *some* of the instances coming within the sweep of the general proposition. Jevons also calls the induction imperfect, where it is impossible to examine all the cases. In imperfect induction there is a passage from the *known* to the *unknown*. It is called imperfect because there can never be perfect certainty about the conclusion owing to the passage from the known to the unknown involved in it. Perfect Induction is certain, but Imperfect Induction is uncertain. When I examine only *some* students of my class and find them to be intelligent, and from this infer that *all* students of my class are intelligent, the inference is called Imperfect Induction. In Perfect Induction the enumeration of particular instances is complete, while in Imperfect Induction, it is incomplete. In Perfect Induction we proceed from *each* to *all*. In Imperfect Induction we proceed from *some* to *all*.

Criticism.

Mill and Bain hold that the so-called Perfect Induction of the Scholastics is not an *inference* at all far less an *induction* for the following reasons:—

In the first place, the conclusion of Perfect Induction does not go *beyond* the premises. It merely sums up the particular facts observed. The so-called Perfect Induction is a mere summation of particulars. There is no *novelty* in the conclusion. Hence it is not an inference.

In the second place, there is no generalisation in it—no passage from the known to the unknown—from the observed to the unobserved—from *some* to *all*. But this 'leap in the dark' is the essential characteristic of induction. Therefore, the so-called Perfect Induction is an *Induction improperly so called* or *Apparent Induction*. It is a mere short-hand registration of facts known. It does not involve any advance in knowledge from the known to the unknown—from *some* to *all*.

J. S. Mill regards the so-called Imperfect Induction of the Scholastics as Induction Proper because here the conclusion goes *beyond* the premises and there is a real inference from the *known* to the *unknown*.

The modern Scientific Induction is a kind of Imperfect Induction in the Scholastic sense. Modern logicians use the terms Perfect Induction and Imperfect Induction in a different sense. By *Perfect Induction* they mean *Scientific Induction*, and by *Imperfect Induction* they mean *Unscientific Induction*. We shall consider the nature of

Scientific and Unscientific Induction below. The Scholastic logicians maintained that Induction is based upon *counting* of instances. But the modern logicians hold that Induction is based upon *analysis* of instances and the establishment of a causal connection.

2. Complete Induction and Incomplete Induction.

Imperfect Induction, in the Scholastic sense, may be divided into two classes, *viz.*, *Complete Induction* and *Incomplete Induction*. An Induction is *complete*, when we establish a *general* proposition after examining *some* particular facts. It is an inference from *some* to *all*—from the *particular* to the *general*. It involves a leap from the *known* to the *unknown*. The conclusion, here, is not a mere summation of particular facts observed. When I examine *some* students of my class and find them to be intelligent, and from this infer that '*all* students of my class are intelligent,' the inference is called Complete Induction.

An Induction is *incomplete*, when we proceed from some known particular facts to some unknown particular fact. It is an inference from *some* to *some*—from particulars to particulars. It is called Incomplete Induction because here we do not proceed from *some* to *all*—we do not reach a *general* proposition, but stop short at some *particular* proposition. When I taste ten mangoes from a basket and find them to be sweet, and infer from this that the eleventh mango also is sweet, the inference is called Incomplete Induction. There is no generalisation in this process of reasoning. Here we do not pass from particular facts to a general law. Here we are not aware of any

causal link. If we could establish a causal link, we would pass from particular cases to a general law. Sometimes 'Complete Induction' is taken in the sense of Scientific Induction, and 'Incomplete Induction', in the sense of Unscientific Induction. We do not take the terms in this sense.

3. Scientific Induction and Unscientific Induction or Induction by Simple Enumeration or Popular Induction.

Complete Induction is divided into two kinds, *viz.*, *Scientific Induction* and *Unscientific Induction.*

A Scientific Induction is the establishment of a real universal proposition based on observation and experiment in reliance upon the Uniformity of Nature and the Law of Causality. We have explained the characteristics of Scientific Induction already. It consists in discovering a *general* law after observing and examining some *particular* phenomena. It is based upon analysis, comparison, variation of circumstances, elimination of irrelevant circumstances, and isolation of relevant circumstances and establishment of a causal connection between the ground of inference and the inferred property. It is proved by the Experimental Methods. It is not based on mere counting or enumeration. "Scientific Induction aims at establishing a universal law that does not refer primarily to cases or instances at all. And the method it employs is to discover the law by analysing the instances and reading it out of them, rather than by merely summing them up. To discover universal principles of

connection through the analysis and comparison of instances is the goal of Scientific Induction."[1]

An Unscientific Induction is the establishment of a universal proposition after an observation of a large number of particular facts. It is based on uniform and uncontradicted experience. It is based upon simple enumeration of particular instances. Here there is neither *analysis* nor *elimination* nor establishment of any *causal connection* by the *Experimental Methods.* It is based on mere counting of instances. We have seen a large number of crows. All the crows that we have seen are black. We have not seen a single crow other than black. So we conclude that "all crows are black." This is an example of Unscientific Induction or Induction by Simple Enumeration. Here we do not analyse the facts observed by us, compare them with one another, eliminate the irrelevant features, and prove any causal connection between the essential qualities of crows and blackness. Similarly, we observe a large number of scarlet flowers and find them to be without fragrance, and infer that "all scarlet flowers are without fragrance." These are Unscientific Inductions or Inductions by Simple Enumeration.

Induction by Simple Enumeration is based on uniform and uncontradicted experience. It is an inference from the *particular* to the *general*—from *some* to *all*. Hence it is a kind of *Complete* Induction. But it is unscientific because it is not proved by the Experimental Methods, and no causal connection is proved in it. It is called Induction by Simple Enumeration because it is based on mere

1 *An Introductory Logic*, pp. 231-32.

enumeration of instances or observation of a large number of particular facts. It relies upon the *Uniformity of Nature.* It does not rely upon the Law of Causation. It is not based upon the establishment of a causal connection. In this process of reasoning we do not know that there is a causal connection. Nor do we know that there is no causal connection. But we vaguely believe that there is some sort of necessary connection, though we cannot prove it.

Induction by Simple Enumeration is drawn from the premises which are not critically examined, while the premises of Scientific Induction are critically examined by the Experimental Methods. In Induction by Simple Enumeration no causal connection is proved between the ground of inference and the inferred property by the Experimental Methods, while in Scientific Induction a causal connection is proved between them by the Experimental Methods. Enumerative Induction means generalisation on the strength of mere *enumeration* or counting of a large number of particular instances, while Scientific Induction means generalisation on the strength of a *causal connection* proved by the Experimental Methods. Enumerative Induction is not based on the Experimental Methods or Methods of Elimination which seek to eliminate irrelevant circumstances and prove a causal connection. It cannot establish a *Law of Nature* ; at best it can give us an *Empirical Law* unverified by the scientific methods. The conclusion of Enumerative Induction is *probable,* while that of Scientific Induction is *certain.* Hence Bacon condemns Induction by Simple Enumeration as "a childish thing, precarious in its conclusions and

exposed to risk from a contradictory instance." If we discover a single white crow, the enumerative induction "all crows are black" will be thrown overboard. In fact, there are crows other than black. At one time, the people thought that "all swans are white;" but later black swans were found in Australia, and thus the previous enumerative induction was disproved. But though Induction by Simple Enumeration is highly precarious, it is not without a value. It often suggests a *hypothesis* which is proved by the Experimental Methods. Thus it becomes a Scientific Induction. The guesses suggested by Induction by Simple Enumeration, when verified by the Experimental Methods, become well-established Scientific Inductions.

4. Induction by Simple Enumeration and Induction by Complete Enumeration.

Induction by Simple Enumeration is an empirical generalisation based on uniform and uncontradicted experience. It depends upon mere *enumeration* or counting of instances like Induction by Complete Enumeration. It differs from the latter in that it depends upon the enumeration of a *large number* of instances, while the latter depends upon the enumeration of *all* the instances. In Induction by Simple Enumeration we reason from *some* to *all*—from a large number of particular facts observed to all similar cases, while in Induction by Complete Enumeration we reason from *each* to *all*. In the former the conclusion goes *beyond* the premises, while in the latter the couclusion is a mere *summation* of the premises. The former is a real inference, while the latter is not. The former is *inductive inference* since it involves an *inductive*

leap or a passage from the known to the unknown, while the latter is not an inference at all, far less an induction. In the Scholastic sense, the former is an *imperfect induction* of incomplete enumeration, while the latter is a *perfect induction* of complete enumeration. Both of them depend upon mere euumeration or counting of instances which is inessential for Scientific Induction. In Scientific Induction we prove a causal connection between two phenomena and on the strength of this establish a general law. In both Induction by Simple Enumeration and Induction by Complete Enumeration we do not establish any causal connection and, therefore, cannot arrive at a certain conclusion. In Induction by Complete Enumeration the conclusion is certain, but this certainty falls short of the certainty of a Scientific Induction which is based upon a causal connection proved by the Experimental Methods. Sometimes both Induction by Simple Enumeration and Induction by Complete Enumeration are called Enumerative Inductions. But we prefer to call the former only Enumerative Induction.

5. The Conditions of Induction by Simple Enumeration.

Induction by Simple Enumeration is less conclusive than Scientific Induction and gives only a probable conclusion. Its value depends upon the following conditions :—

(1) The number of instances must be very large. The larger the number of instances observed, the greater the probability of the conclusion. The multiplication of instances increases its probability.

(2) The instances must be gathered from a wide range of experience so that there may be a presumption that there are no contrary instances. But if the range of experience is limited, there is a likelihood that there may be contrary instances outside our experience. A single contrary instance must not be found. It will frustrate the generalisation. If a single white crow is found, the enumerative induction "all crows are black" falls to the ground. Enumerative Inductions are empirical generalisations about phenomena of such frequent occurrence that had there been any exception it must have come to our notice. If they are built upon limited experience, they become extremely precarious.

6. The Value of Enumerative Induction.

Enumerative Induction is based on mere counting of instances. But mere enumeration of instances cannot give a certain conclusion. Even if we find two phenomena conjoined in thousands of instances, it does not warrant us in asserting that they are *always* conjoined. But still it gives us a presumption that they may be necessarily connected always. If *various kinds* of positive instances are examined, the value of the conclusion is increased. For example, if we examine various kinds of scarlet flowers in many countries and find them to be devoid of fragrance, and then infer that "all scarlet flowers are devoid of fragrance", the conclusion will become more probable. "Induction by simple enumeration rests then on an implied elimination, but the elimination is half-conscious, and mostly incomplete, and therefore the exclusion is of very problematic value."[1]

1 Joseph: *Introduction to Logic*, p. 491.

(1) Induction by Simple Enumeration is not entirely a childish thing, as Bacon says. It is of great practical value. It lies at the root of many *popular generalisations.* Its value increases with the multiplication of instances from a wide range of experience.

(2) Enumerative Induction is a fruitful *source of discovery.* It very often suggests *hypotheses* which, when verified by the Experimental Methods, become "scientific inductions." Thus it serves a useful purpose in inductive investigation. Though often erroneous, sometimes it proves true and points to a real causal connection somewhere. Induction by Simple Enumeration suggests Empirical Laws which are often tested and verified by the Inductive Methods and exalted to the rank of Scientific Inductions.

7. Processes Simulating Induction or Apparent Inductions.

There are certain processes of inference which appear to be inductive though they are really not so. They appear to be inductions. They are called by Mill Apparent Inductions. There are three forms of Apparent Inductions or Inductions improperly so-called.

(1) Perfect Induction of Scholastics.

We have already learnt that Perfect Induction, according to the Scholastics, is an Induction by complete enumeration. It is an inference from *each* to *all*; in it we establish a general proposition after examining *all* the instances coming within its sweep. When, for instance, after examining all the books in a library one by one and finding them to be English we come to the conclusion

that "all the books in the library are English," the process of inference is called Perfect Induction.

Criticism.

Mill rightly urges that the so-called Perfect Induction is no *inference* at all,—far less an induction. Here the conclusion is a mere summation of particular facts observed. It does not convey any new information. It merely sums up what is conveyed by the particular instances observed. It does not even make explicit what is implicit in the particular premises. It does not advance our knowledge. It is not an *inductive* inference because there is no 'hazardous leap in the dark'—no passage from the known to the unknown in it, which is the essential feature of inductive inference. It is not an induction.

(2) Parity of Reasoning or Induction by Parity of Reasoning.

Induction by Parity of Reasoning is the establishment of a *general proposition* on the ground that *the same reasoning* which proves a particular case will prove all similar cases. Parity or similarity of reasoning is the ground of passing from a particular case to the general proposition. It is illustrated in *geometrical proofs.* The proofs of Euclid are sometimes regarded as inductive because a certain truth proved by reference to a particular diagram is generalised and extended to all similar cases. For example, the three angles of a triangle are proved to be equal to two right angles with regard to a particular diagram drawn on a piece of paper or a black-board; and this truth which holds good of this particular diagram

is extended to all other triangles. Here, the argument appears to be inductive because it seems to proceed from a particular instance to a general proposition.

Criticism.

(*i*) Here the process of reasoning seemingly proceeds from the particular to the general; but in reality it does not proceed from the *particular* diagram by which it proves a general truth to all other similar cases. The particular diagram serves the purpose of a concrete example. The proof does not depend upon the size and shape of the triangle. It does not depend upon the length of its sides or the magnitude of its angles. The diagram is regarded not as a particular triangle but as a *type* of all triangles. One triangle is as good as any other for the purpose. We exclude from the reasoning all reference to the size of the triangle, the length of the sides, the magnitude of the angles, etc. Therefore, our proof is independent of any one of these particular features of the diagram, and holds under all variations of each. The proof is couched in *general* language, It is applicable to all triangles. The diagram illustrates the proof. It is not used as a fact of observation, but helps us in following the general argument.

(*ii*) Geometrical proofs are really *deductive* in character. They are deductions from definitions, axioms, postulates, and the general truths established in previous theorems. For example, the general proposition 'all triangles have their three angles equal to two right angles' follows *deductively* from the *definition* of a triangle as

'a plane figure bounded by three straight lines.' The property of a triangle follows deductively from its definition or connotation.

(*iii*) Mill regards a geometrical proof as *Induction by Parity of Reasoning.* Parity means similarity. The general conclusion in this form of reasoning is based on the belief that *the same reasoning* applies to all cases under the same conditions. For instance, the same reasoning which applies to a particular diagram of a triangle will apply to any other diagram of a triangle. Parity of Reasoning is not an induction. There is no observation of particular instances here. Here the general proposition is not based on the evidence of particular instances.

(3) Colligation of Facts.

This term was first coined by Whewell. Colligation of facts, according to him, means "the act of bringing a number of facts actually observed under a general description." It is the act of colligating or binding together a number of facts observed by means of a suitable conception It is the mental union of particular facts observed by a hypothesis. Kepler made a series of observations and noted the successive positions of Mars and then made a hypothesis that these points in the orbit of Mars could be suitably connected together by drawing an ellipse. This process of inference is called Colligation of Facts. A navigator coasting along a tract of land comes back to the place from which he started. Then he declares it to be an island. Here also the successive positions are connected together by the conception of island. This also is Colligation of Facts. Whewell

identifies it with Induction. He holds that the framing of a hypothesis after observation of facts is the essential part in inductive investigation.

But Mill contends that Colligation of Facts is a mere summation of facts. It cannot be identified with induction. Framing of a hypothesis is a preliminary step in inductive investigation. A hypothesis is a mere guess. It becomes an induction, when it is verified by the Experimental Methods. Colligation of Facts by a suitable conception or hypothesis is subsidiary to induction. It cannot be identified with induction.

Whewell urges that colligation is more than a mere summation of facts. It introduces a principle of connection into facts, which is supplied by the mind. "Colligation introduces, as a principle of connection, a conception of the mind not existing in the facts." (*Whewell*). Colligation, therefore, is not a mere summary of facts.

Criticism.

Both Whewell and Mill are partly right. Whewell is right in holding that colligation is more than a mere summary of facts. It introduces a principle of connection into particular facts observed. It binds observed facts together by a *hypothesis* or a mental conception. But Whewell is wrong in holding that colligation is identical with Induction. Mill is right in holding that Colligation of Facts by a hypothesis is a preliminary step in inductive investigation. The framing of a hypothesis is indispensably necessary for inductive investigation, but it is subsidiary to induction. It cannot be identified with induction. The hypothesis is a mere conjecture. When

it is proved by the Experimental Methods, it becomes an induction. Colligation is a *description* of a set of particular facts observed in general terms. It is an *unverified generalisation.* It does not *explain* the phenomena. When it is verified by the Experimental Methods, it is exalted to the rank of scientific induction. Colligation cannot be identified with induction. Colligation does not prove any causal connection. But scientific induction is based upon the establishment of a causal connection. Hence Mill concludes that colligation is subsidiary to induction but cannot be identified with induction. Induction is something more than colligation. Every Induction involves colligation, but every colligation is not an Induction. "*Induction is Colligation but Colligation is not necessarily Induction.*" (*Mill*).

Colligation is an Apparent Induction. It is contended by some that in this process of reasoning we seemingly proceed from particular facts to a general hypothesis. But really we proceed from a general conception of the whole to its parts ; we *deduce* the *parts* from the conception of the *whole.* The process of reasoning is really *deductive* and not inductive. We connect the different positions of Mars by drawing an ellipse because we are already acquainted with the properties of an ellipse. If we were not familiar with the properties of an ellipse, we could not possibly surmise that the orbit of Mars is elliptic after observing some of its positions. Here we really *deduce* the character of the orbit of Mars from our general notion of the properties of an ellipse. Similarly, we connect the different positions of the coast of an island because we

have already the notion of 'island' in our minds. The process of reasoning is really *deductive* in character. It proceeds from the *whole* to its *parts*—from *all* to *some*. It does not proceed from the parts to the whole, though it appears to do so.

8. The Inductive Procedure: Steps in Scientific Induction.

Scientific Induction aims at discovering the general laws of nature by a critical examination of particular phenomena of nature. It usually requires the examination of a considerable number of instances. "But the general proposition is not obtained by simply counting the instances, or by adding them together. The purpose of taking a number of instances is to facilitate *analysis*, to aid us in *eliminating* characters or circumstances that are *accidental or irrelevant*, and at the same time, through these exclusions, to exhibit and *define* more clearly the *essential* character and relations of the subject we are investigating. The process of *analysis* is thus at the same time a process of *synthesis*; the process of excluding the irrevelant, a process of defining the essential."[1] Thus Scientific Induction is Induction through analysis. It is not an enumerative induction. In involves the following steps :—

(1) Collection of Data or particular facts by Observation and Experiment.

The first step in inductive investigation is the collection of the data or premises of inductive inference. The data of induction are particular facts. They are gathered

1 *An Introductory Logic*, pp. 233—34.

from experience. They are not assumed to be true. They are actually observed. They are derived from observation and experiment. Therefore, observation and experiment are called the material grounds of induction. They supply the material, data, or premises of inductive inference. Scientific induction consists in reading a law of nature out of particular phenomena of nature observed.

Now, observation is well-regulated perception. It is perception of particular facts for a definite purpose. Before we begin observation we should clearly *define* the phenomenon under investigation. We should clearly ascertain the nature of the phenomenon we want to explain. We should *select* the instances with reference to the purpose of the investigation. Hence observation involves *definition*.

Nature is extremely complex. The phenomena of nature are blended together. Facts are not presented to us in isolation. So, first, we should *analyse* the complex phenomenon under investigation into its constituent factors. Then we should try to ascertain which of these factors are irrelevant and accidental, and which of them are relevant and essential. In order to find out the cause of a phenomenon we should *eliminate* the irrelevant and accidental circumstances and *isolate* the relevant and essential circumstances. Elimination of accidental circumstances and isolation of essential circumstances suggest a causal connection. Elimination requires what Bacon calls varying the circumstances. We should observe the phenomenon under a variety of conditions. We should collect various combinations of the phenomenon under

investigation, and find out by successive elimination of different circumstances, what circumstances are *constantly* conjoined, and what are merely accidentally present.

Thus we *define* the phenomenon under investigation, *analyse* it into its constituent factors, *observe* it under a *variety of conditions*, *eliminate* the irrelevant and accidental circumstances, and *isolate* the relevant and essential ones. *Hence observation involves definition, analysis and elimination by varying the circumstances.*

(2) Framing of a Hypothesis.

The second step in inductive investigation consists in the framing of a *Hypothesis*. After we *observe* the phenomenon under investigation under a variety of conditions, *analyse* the circumstances into relevant and irrelevant conditions, *eliminate* the irrelevant circumstances and *isolate* the relevant ones, we frame a *hypothesis*. It is a guess or conjecture as to the probable cause of a given event. We frame a hypothesis because we cannot all of a sudden hit upon the real cause of a phenomenon. So we make a supposition as to the cause of the phenomenon. This framing of a hypothesis requires a stroke of genius or creative imagination. A hypothesis is an attempt at explanation. If one hypothesis cannot adequately explain the phenomenon under investigation, it should be replaced by a better hypothesis.

(3) Employment of the Inductive or Experimental Methods.

The third step in inductive investigation is the *verification* of the hypothesis by the *Inductive or Experimental Methods*. A hypothesis is a mere guess or

supposition as to the probable cause of a phenomenon. It is a mere assumption based on inadequate or insufficient evidence. So it must be verified by the Experimental Methods which are devices for proving a causal connection. They are methods of elimination. They vary the circumstances of the phenomenon under investigation, eliminate the accidental circumstances and isolate the relevant and essential ones, and establish a causal connection between two phenomena which are constantly conjoined. The Experimental Methods establish a causal connection which is previously suggested by a hypothesis. An unverified hypothesis can never be regarded as an induction. Discovery of a hypothesis is an indispensable preliminary to induction. But the *proof* of a hypothesis by the employment of the Experimental Methods is the essential step in inductive investigation. We cannot arrive at a scientific induction unless we prove a causal connection, and we cannot prove a causal connection without employing the Experimental Methods. So the employment of the Experimental Methods is a very important step in the inductive method.

(4) Generalisation or Inductive Inference.

When we establish a causal connection between two phenomena with the help of the Experimental or Inductive Methods, we can infer a general proposition. We can proceed from particular facts observed to a general law when we have proved a causal connection. The process of inference from particular truths to a general truth on the ground of a causal connection established by the

Experimental Methods is induction or generalisation proper. This is the process of inductive inference.

(5) Verification.

The last step in inductive investigation is the ***verification*** of the induction established by the Experimental Methods In inductive inference we always proceed from particular facts to a general law. The general law is first suggested to us as a hypothesis. It is verified by deduction. We deduce consequences from a hypothesis and compare them with facts of actual observation. If they tally with each other, we regard the hypothesis as valid. Sometimes we verify a general law reached by generalisation from particular facts by deducing it from known laws. "We confirm the inferred generalisation, or we may succeed in absolutely demonstrating it by showing that it follows from a combination of various known laws."

We observe on a number of clear nights that thick dew is deposited on the ground, and generalise from these facts that 'on *all* clear nights dew is deposited'. This generalisation is verified by showing that on a clear night there is rapid radiation from the earth. that the moist air is therefore in contact with a cold soil, that the air becomes cool in contact with the cold soil. and that cool air cannot contain so much moisture as warm air. Therefore dew is deposited on clear nights.

Different logicians lay stress on different steps in inductive investigation. *Bacon* emphasises the first step. He looks upon *analysis and elimination by varying the circumstances* as the most important step in the inductive method. *Whewell* regards the *framing of a hypothesis* as the most important step. According to him -Induction is concerned

---

1 Venn : *Empirical Logic*, p. 353.

with Discovery. *Mill* regards *generalisation* by employing the *Inductive or Experimental Methods* as the most important step. According to him Induction is concerned with Proof. It is not mere discovery of a hypothesis, but its proof by the inductive methods. *Jevons* regards *verification* as the most important step in inductive investigation. Inductive generalisation must be verified by Deduction.

Suppose we want to investigate the cause of *malaria*. First, we should *define* the nature of the disease. Malaria begins with shivering and the temperature shoots up ; it is attended with thirst and pain in the head. We *observe* a large number of patients suffering from malaria, of different ages, of different occupations, living in different places with different climates, in different seasons of the year. We observe the kinds of food taken by them, the clothes worn by them, the peculiarities of their constitutions, the nature of the environment in which they live, and so on. We observe the phenomenon under different sets of circumstances. We *vary the circumstances* of the phenomenon and try to find out what are the relevant conditions and what are merely accidental conditions ; age, occupation, physical constitution, food, etc., are irrelevant conditions because they are present in some instances and absent in others. In this way, we eliminate the irrelevant circumstances and isolate the relevant ones. We find that wherever stagnant water collects and mosquitoes breed, there is outbreak of malaria. Then we *frame a hypothesis* that malaria may be due to mosquito-bite. Malaria germs are carried by mosquitoes. We try to verify the hypothesis by the *Experimental Methods.* We find that the persons who use mosquito-curtains are comparatively free from malaria. But those who do not use mosquito-curtains and are exposed to mosquito-bite very often suffer from malaria. These facts strengthen our presumption that mosquito-bite is the cause of malaria. If we find in certain cases that some healthy persons are actually bitten by female anopheles mosquitoes and suffer from malaria, while others in the same locality who take every precaution to avoid

mosquito-bite are free from malaria, the *hypothesis is verified*, and we conclude that female anopheles mosquitoes are carriers of malaria bacilli. They suck in the malaria germs from patients suffering from malaria with their blood and inject them into healthy persons. Thus we prove a causal connection between malaria and bite of female anopheles moqnitoes. On the strength of this causal connection we *generalise* and arrive at the proposition "all cases of malaria are due to mosquito-bite of a particular species." We next attempt to *verify this generalisation.* We deduce consequences from it and compare it with facts of actual observation. If anopheles mosquitoes are carriers of malaria germs, then those persons who always use mosquito-curtains will be free from malaria, while those who never use mosquito-curtains will suffer from malaria ; and those who are bitten by other mosquitoes will not suffer from malaria. And these facts are actually found in experience. Thus the generalisation is verified by *deduction* and fresh *observation* of other facts.

9. The Inductive Syllogism.

(1) Aristotle does not recognise Induction as a distinct kind of reasoning. According to him, Induction is a *syllogism* which proves the major term of the middle by means of the minor. He takes the major, minor, and middle terms in ***denotation.*** The major term has the widest denotation. The minor term has the least denotation. The denotation of the middle term is greater than that of the minor term and less than that of the major term. Aristotle resolves an Induction into a syllogism of the ***third figure.***

John, James, Jones and others are mortal ;

John, James, Jones and others are *all* men :

∴ All men are mortal.

This is a syllogism of the third figure. Here the predicate of the conclusion "mortal" is of the *widest extent*; so it is the *major* term. The subject of the conclusion "men" is of *medium extent* ; so it is the *middle* term. And the subject of each premise "John, James, Jones and others" is of the *least extent* ; so it is the *minor* term. The syllogism proves the major term of the middle term by means of the minor term.

Criticism.

But the attempt of Aristotle is futile. How do we get the premise 'John, James, Jones and others are *all* men" ? Have we examined *all* human beings ? If so, the general conclusion is a perfect induction or mere summation of particular facts observed. If not, how can we get the premise without *induction* ? The essential feature of Induction lies in the passage from the known to the unknown. We must derive the premise 'John, James, Jones and others are *all* men' by induction, because we cannot observe every human being. Aristotle holds that Induction is the process of reasoning from the parts to the whole. We determine the nature of the whole by examining the nature of some parts. If all parts are examined, then Induction is a mere summation of particulars, and not a real induction. If some parts are examined, then Induction cannot be reduced to a syllogism because it passes from the known to the unknown. Moreover, the Deductive Syllogism is based upon the dictum that whatever is predicated of the *whole*, can be predicated, in a like manner, of the *parts*. But the Inductive Syllogism of Aristotle is based on

the dictum that whatever is predicated of the *parts*, can be predicated, in a like manner, of the *whole*. Therefore, Induction cannot be reduced to a syllogism. It is a distinct kind of reasoning different from deduction.

(2) **Aldrich** and **Whately** resolve an Induction into a syllogism in the following way :—

The men whom we have observed and *the men we have not observed* are mortal ;

All men are the men whom we have observed and the men whom we have not observed :

∴ All men are mortal.

Here the major premise assumes the very point to be established, and involves the inductive leap. What is the ground of the major premise ? How do we know that the men whom we have not observed are mortal ? We may have observed some men to be mortal. But we have no right to assume that the men whom we have not observed are mortal. We can never pass from the known to the unknown—from the observed to the unobserved cases—by means of deduction. So the ultimate guarantee of the major premise is Inductive Generalisation.

(3) **Mill** reduces an Induction into a syllogism with the Uniformity of Nature as the major premise and the particular facts observed as the minor. Thus the inductive inference—'John is motal ; James is mortal ; Jones is mortal : ∴ All men are mortal' may be reduced to the following syllogism :—

What is true of *some* members of a class under certain conditions is true of *all* the members of the class under the same conditions ;

Mortality is true of John, James and Jones, who are *some* members of the class of 'men' under the same conditions (*i.e.*, when human nature is present in them);

∴ Mortality is true of *all* members of the class of 'men' under the same conditions (*i.e.* all men are mortal).

The Uniformity of Nature is the postulate of Induction. It is a self-evident ultimate principle. It cannot be proved by Induction or Deduction. It may be regarded as the ultimate major premise of Induction.

10. History of Induction.

Induction has been conceived in three different ways in three periods of history. Aristotelian Induction, the Scholastic Induction, and the modern Induction are three distinct stages in the history of the Inductive Method.

(1) The Aristotelian Induction.

Aristotle described Induction as ascending from the particular to the universal in the sense of recognising the universal in the particular. It proceeds from observation of particular cases to universal laws, from consideration of parts to the knowledge of the whole. He reduces an Induction to a syllogism of the third figure. We have seen that his Inductive Syllogism is based upon the dictum that whatever can be predicated of the parts can be predicated, in a like manner, of the whole. His Inductive Syllogism is valid if the second premise is simply convertible.

All S (*i. e.* A, B, C, etc.) is P,
All S (*i. e.* A, B, C, etc.) is *all* M;
∴ All M is P.

The conclusion in the third figure is particular. But here it is universal because the predicate of the second premise is quantified and distributed, and the premise is simply convertible. If the second premise is based on an examination of *all* the instances, it is a perfect induction. But Aristotle does not hold that the universal proposition is established by examining all the instances that come under it. "He seems to take the position that the universal is derived from the particulars not in the sense that we infer it from them but in the sense that they enable us to recognise it. The particulars do not prove the universal. We recognise it by means of them, but we do not infer it from them. Thus the process of induction becomes not inference, but direct insight."[1] According to Aristotle, inductive syllogism does not involve perfect induction or exhaustive enumeration of individuals, though his illustrations contain a suggestion of enumeration. The enumerative aspect of induction was emphasized by the mediæval logicians. Aristotle seems to hold that the universal is *suggested* by the particular instances observed ; we recognise the universal in particulars.

(2) The Induction of the Scholastic Logicians.

In the middle ages the Scholastic logicians emphasized the enumerative aspect of induction. According to them, the essence of induction consists in *enumeration* or counting of instances. They divide induction into two kinds, *viz.*, Perfect Induction and Imperfect Induction. Perfect Induction is Induction by Complete Enumeration.

1 *The elements of Logic* ; p. 268.

Imperfect Induction is Induction by Incomplete Enumeration or Induction by Simple Enumeration.

But enumeration or counting of instances cannot establish an induction. Even if we find two phenomena (*e. g.* the sky and the ocean) constantly conjoined in numerous instances, we cannot establish any causal connection between them. Analysis and elimination are indispensable for proving a causal connection. And this aspect of the inductive method was emphasized by Bacon and Mill.

(3) The Modern Induction.

Francis Bacon is the father of the modern Induction. According to him, the aim of Induction is the interpretation of nature or discovery of the laws of nature. This end cannot be realised by mere counting of instances. Induction by Simple Enumeration is "a childish thing, precarious in its conclusions and exposed to risk from a contrary instance." The laws of nature cannot be obtained by enumeration, complete or incomplete. For enumeration cannot establish necessity or causal connection. Scientific Induction tries to establish necessary connection, or causal relationships. Enumeration, therefore, cannot satisfy its requirements. Bacon emphasizes *observation. analysis and elimination by varying the circumstances* in the inductive method. He does not recognise the importance of framing a hypothesis in scientific investigation. He suggests the Inductive or Experimental Methods in a crude form, which were elaborated by Mill later. We should observe particular facts of nature selected for the purpose of discovering the

cause of a phenomenon and arrange them in three tables : (1) *the Table of Presence* which is to contain *positive* instances of the phenomenon under investigation *i. e.* instances of the *presence* of the phenomenon ; (2) *the table of Absence* which is to contain *negative* instances of the phenomenon *i. e.* instances of the *absence* of the phenomenon ; and (3) *the Table of Degrees* which is to contain instances of the *presence* of the phenomenon *in varying degrees.* These three tables were elaborated by J. S. Mill into the *Methods of Agreement*, *Difference*, and *Concomitant Variations.* This is Bacon's *methods of exclusion or elimination by varying the circumstances.*

J. S. Mill elaborated the Baconian Induction. He defines Induction as "the operation of discovering and proving general propositions." "Induction is that operation of the mind, by which we infer that what we know to be true in a particular case or cases, will be true in all cases which resemble the former in certain assignable respects." Induction "consists in drawing inferences from known cases to unknown." The inductive leap constitutes the essence of induction. Perfect Induction of the Scholastics is "not an inference from facts known to facts unknown, but a mere short-hand registration of facts known." Imperfect Induction of the Scholastics is an unscientific induction. It proceeds from the known to the unknown ; but it does not prove any causal connection. Mill emphasizes the establishment of a causal connection as the most important step in the inductive method. He formulates his famous *Experimental Methods* which are devices for proving causal connection among phenomena.

He underestimates the importance of a hypothesis in induction. According to him, Induction is concerned with *proof*, and not with discovery. The establishment of causal connection is the essence of the modern induction. It does not depend upon mere enumeration of instances. It depends upon analysis and elimination by varying the circumstances with the help of the Experimental Methods. Mill's Induction is an elaboration of the Baconian Induction. It relies upon the *Uniformity of Nature* and the *Law of Causation*[1].

QUESTIONS

1. Distinguish between Perfect and Imperfect Induction. Which of them is Induction proper, and why?

2. Distinguish between Complete and Incomplete Induction?

3. What is Induction by Simple Enumeration? How does it differ from Scientific Induction? How is it related to Scientific Induction?

4. Explain clearly the nature of Scientific Induction.

5. Discuss the logical value of Induction based on complete enumeration of instances.

6. What are the different kinds of processes that simulate induction? Explain and illustrate each of them, and explain in each case why the process is not a real induction.

7. Are the proofs of Geometry inductive or deductive? Discuss.

8. Distinguish Scientific Induction from other kinds of inference improperly called Induction. Illustrate your answer.

9. What is the essential nature of inductive inference? In the light of your answer, examine the claim of Colligation of Facts

---

1 Welton: *Manual of Logic*, Vol. II, pp. 32–48.

and Complete Enumeration of instances as processes of inductive inference.

10. Explain and illustrate the following :—

(*i*) Colligation of Facts.

(*ii*) Perfect Induction.

(*iii*) Parity of Reasoning.

(*iv*) Inductive Syllogism.

11. Distinguish between Induction and Colligation of Facts. How are they related to each other ?

12. Can Induction be reduced to syllogistic reasoning ? Fully discuss this question, examining the different attempts that have been made to resolve the former into the latter.

13. Distinguish the various senses in which the word 'Induction' has been taken. Explain clearly the nature of Scientific Induction.

14. Explain clearly the different steps in the Inductive Method.

CHAPTER III

THE FORMAL GROUNDS OR POSTULATES OF INDUCTION

1. The Presuppositions of Induction.

Induction is the process of reasoning from particular facts to a general law. It proceeds from particular truths to a general truth. The 'inductive leap' is the essence of the inductive inference. It proceeds from the present to the past, distant and future. But how can we pass from observed facts to unobserved facts? What justifies us in passing from the known to the unknown?

It is our belief in the *Uniformity of Nature* and the *Law of Causation* that warrants us in passing from the known to the unknown. The inductive leap is justified by two postulates, (*i*) that nature is uniform, (*ii*) that every event must have a cause. Scientific Induction starts with particular facts and establishes universal laws. It extends the relation which is found to be true here and now in particular facts to cover all cases of the same kind, past, present and future. It observes that 'John is mortal,' 'Jones is mortal', 'James is mortal,' 'Mohan is mortal,' and infers that 'all men are mortal.' It can generalise because it believes in the postulates of Uniformity of Nature and Law of Causation. It can pass from the particular truths to the general truth, if it can establish a causal connection between the essential quality of men and mortality. It can generalise from particular facts because it believes that every event has a cause and the same cause produces

the same effect under the same conditions. If it can prove that the essential quality of men is the cause of mortality, then it can easily infer that the same cause produces the same effect under the same circumstances. In other words, wherever there is the essence of man there is mortality, *i. e.* 'all men are mortal.'

Thus the Uniformity of Nature and the Law of Causality are the presuppositions of Induction. They are called the formal grounds of Induction. The Uniformity of Nature means that the Reality is a *system* of interconnected parts, which remains *identical* in the midst of changes. It means the *Unity of Nature* or *identity* of nature in the midst of *variety*. In simple language, it means that Nature is a system of events which are governed by laws. The Law of Causality means that the parts of nature are *causally* connected with other parts: every event is causally related to other events. The Uniformity of Nature emphasises the *identity* and the systematic *unity* of the *whole*. The Law of Causality emphasises the *causal* relation among the *parts* within the whole. Thus they are related to each other. If the Reality were a chaos of disconnected parts, no induction would be possible. If all events in nature were spontaneous or uncaused, without any relation to one another and to the whole, induction would be impossible. Therefore, the Uniformity of Nature and the Law of Causation are the postulates of Induction.

2. The Uniformity of Nature

The Uniformity of Nature means that nature acts in the same way everywhere and at all times under the same circumstances. It has been expressed in various ways:

(1) "Nature is uniform"; (2) "Nature repeats itself"; (3) "Under certain circumstances, what has been will be"; (4) "The future will resemble the past"; (5) "Nature has parallel cases"; (6) "The Universe is governed by laws"; (7) "The same cause will always produce the same effect," and so an. All these expressions mean that *Nature behaves in the same way under the same circumstances.* Nature is never whimsical or capricious. Nature has no freaks or whims. The phenomena of Nature are governed by fixed laws. If fire burnt in the past, it will burn in future also under the same conditions. If water quenched thirst in the past, it will quench thirst in future also.

But here we must avoid a misconception. The Uniformity of Nature does not mean that there is no variety in nature. "The course of nature, in truth, is not only *uniform*, it is also infinitely *various*". (*Mill*), There is *identity in variety* in nature. There are various phenomena of nature, which are governed by the same law. The events which are governed by the same law are not identical. The same events never recur. They are different from one another. But they are similar in nature and governed by the same law. Ebb and tide, motions of the planets, gravitation of the earth are different from one another; they are yet governed by the same law of attraction. They exhibit uniformity of behaviour. This fire or that fire burns. These instances are not identical with one another; they are different and yet show uniformity of behaviour. The Uniformity of Nature recognises both *identity* and variety in nature.

Some events of nature (*e. g.* earthquake) seem to be violations of the laws of nature. They seem to be governed

by no laws. This misconception is due to our ignorance. Every event in nature is governed by a law, whether we know it or not. Nature is intelligible to us only if we conceive of it as a system of inter-connected events governed by laws. If it were a heap of disconnected events without any uniformity of relations, it would be utterly unintelligible and inexplicable.

There are different departments of the Reality. The phenomena in these departments are governed by different uniformities or laws. There are the laws of Physics, the laws of Chemistry, the laws of Botany, the laws of Physiology, the laws of Psychology, the laws of Sociology, etc. These laws govern different kinds of phenomena. They are inter-related to one another, though we have not yet been able to comprehend their inter-relation. Bain says: "The course of the world is not *a* Uniformity, but *Uniformities*". By this he means that the whole of nature is not subject to one law. There are different laws which govern the different departments of nature. But Bain seems to underestimate the inter-relation among different laws of nature. The different laws are related to one another; they are parts of one whole.

Nature is a system of inter-connected parts. The events of nature are related to one another and determined by the whole. They are necessary parts of a system. The whole determines the parts and the parts determine one another and the whole. The parts are organically related to one another within the systematic unity of the whole. The whole remains *identical* in the midst of its *changing* parts. The *Unity of Nature* expresses

the truth better than the Uniformity of Nature. "By this we do not mean", Welton rightly says, "that the universe is an unchanging identity, but that it is a system which remains *identical* with itself amdist the unceasing *changes* of relations between its parts, and which by its own nature, necessitates and determines those changes. But every relation, and, consequently, every change of relation is *universal*; in other words, it holds true everywhere and always, of all identical facts. Hence the idea of Unity of Nature implies that of Uniformity."[1]

3. The Law of Causation.

The Law of Causation means two things.

(1) "Every event must have a cause." "Whatever happens has a cause."

(2) "The same cause produces the same effect under the same conditions."

In the first place, the law of causation means that there can be no event without a cause. An event is a happening or a change in nature. Whenever an event comes into existence it must be brought about by a prior event. "Every phenomenon which has a beginning must have a cause." (*Mill*). There can be no uncaused events. There are no miracles in nature. There is no scope of chance or accident in nature. We speak of chance owing to our ignorance of causes. All phenomena are determined by their causes. Nature is a system of changing events which are causally determined by other events. Nature is not a chaos of unconnected spontaneous events.

1 *Manual of Logic*, Volume II, p. 5.

In the second place, the law of causation means that the same cause must produce the same effect under the same circumstances. This is called the *Uniformity of Causation.* There is a necessary connection between a cause and its effect. Therefore, the same cause will always produce the same effect, and the same effect will always be produced by the same cause. The same cause must always have the same effect. The same effect must always have the same cause.

The Law of Causation denies two things. "First, it denies pure spontaneity of commencement. If the law is true, no change arises out of vacuity or stillness ; there must be some prior event, change, or movement, as a *sine qua non* of the occurrence of any new event. A fire never bursts out without some commencing circumstance, in the shape of movement, change, or activity".

"Secondly, the law denies that events follow one another irregularly, indiscriminately, or capriciously. The same circumstances that make a fire burst out to-day, will, if repeated, make it burst out to-morrow, or at any future time. In short, the law is the statement of *uniformity* in the succession of events."[1]

4. Relation of the Law of Causation to the Uniformity of Nature.

According to **Mill, Bain,** and others, the Law of Causation is a special kind of the Uniformity of Nature. Bain divides the Uniformities of Nature into Uniformities of Co-existence and Uniformities of Succession. The Uniformities of Co-existence are found in geometrical

1 Bain : *Inductive Logic*, p. 16.

figures. The Uniformities of Succession are of two kinds, *viz.*, the uniformity of succession between the co-effects of the same cause (*e.g.* day and night), and the uniformity of succession between causes and effects or the Law of Causation. The law of causation is a special kind of the Uniformity of Nature. It is the uniformity of causation. It implies that the same cause is always followed by the same effect. The Law of Causation not only means that (*i*) *every event has a cause*, but also that (*ii*) *the same cause has always the same effect under the same conditions.* In this wider sense, the Law of Causation is included in the Uniformity of Nature.

According to **Joseph** and others, the Law of Causation involves the Uniformity of Nature. Causation implies necessary connection between cause and effect. If A is the cause of B, A must always produce B and B must always be produced by A. If they are not necessarily connected, they cannot be said to be causally connected. The very notion of causality necessarily involves the notion of uniformity. A cause must necessarily act uniformly. The causal connection is a necessary connection. It is, therefore, a universal connection. If A is the cause of B now, it must be so always. "There is no need then to distinguish the Law of Causation from the Uniformity of Nature ; for a cause which does not act uniformly is no cause at all." Therefore, causality cannot be derived from uniformity of sequence, but uniformity of sequence is derived from causality.

According to **Sigwart, Bosanquet** and others, the Law of Causation is quite distinct from the Uniformity of

Nature. They are two distinct fundamental principles. The Law of Causation simply means that *every event has a cause.* In order to assert that *the same cause must produce the same effect under the same conditions,* we must take the help of the Uniformity of Nature. The Uniformity of Causation is an aspect of the Uniformity of Nature. But the Law of Causation in the sense that every event must have a cause is not a part of the Uniformity of Nature. We may grant that 'every event must have a cause' (Causation), but it does not follow from this that 'the same cause must always have the same effect' (Uniformity of Causation). In order to assert that the same cause *must have the same effect,* we must take the help of the Uniformity of Nature. The Uniformity of Causation is an aspect of the Uniformity of Nature. But the Law of Causation in the sense that every event must have a cause is not a part of the Uniformity of Nature. It is quite distinct from the Uniformity of Nature. Thus the Law of Causation and the Uniformity of Nature are distinct from each other. In this sense, both of them are the formal grounds of Induction ; or, the Law of Causation as modified by the Uniformity of Nature may be said to be the presupposition of Induction.

We should bear in mind that the Uniformity of Nature is the formal ground of all kinds of induction, scientific and unscientific, but the Law of Causality is the formal ground of Scientific Induction only. In scientific induction we must prove a causal connection between the ground of inference and the inferred property.

5. The Formal Grounds or Presuppositions of Induction.

Let us show how the Uniformity of Nature and the Law of Causality are presupposed by Induction.

Let us take an example of inductive inference :—

John is mortal,
James is mortal,
William is mortal ;
∴ All men are mortal.

In this example we pass from the particular facts observed to all other similar cases. We pass from *some* to *all*. We pass from the observed to the unobserved. But what is the guarantee of our passing from the known to the unknown ? What justifies us in passing from the observed to the unobserved ?

It is our belief in the Uniformity of Nature and the Law of Causality. Both of them are presupposed by the inductive inference. For example, first of all, we must be quite sure that John, James and William are uniform in nature or similar in their essential qualities. In fact, we must know that all men, wherever they may be and whenever they may be, must have *community of essence* or Uniformity of Nature. Otherwise, we can never prove that all men are mortal. We cannot pass from the particular to the general, from the observed to the unobserved, from the present to the past, the remote and the future, unless we *assume* that Nature will behave in the same way under the same circumstances.

We must not only know that all men have community of essence or Uniformity of Nature, but we must also

know that mortality is the *effect* of the essential nature of man. By applying the inductive methods to the three cases observed, we must prove a *causal connection* between the essence of men (in which John, James and William participate) and mortality. If we cannot prove a causal connection between the two,—though we know that all men are similar in their essential nature,—we can never prove that all men are mortal after observing the mortality of John, James and William. So the establishment of a causal connection between the *essence* of men and *mortality* is indispensable for the inductive inference.

When we prove that there is a causal connection between the two with the help of the experimental methods, we can legitimately conclude that wherever there is the essence of men there is mortality, because *the same cause produces the same effect under the same circumstances.* In other words, we can prove that all men are mortal. Thus, Induction presupposes both the Uniformity of Nature and the Law of Causation.

6. The Origin of Belief in the Uniformity of Nature.

I. The Empiricist view.

J. S. Mill holds that the belief in the Uniformity of Nature is based on *experience.* It is derived from observation of particular facts by generalisation. We always see that fire burns, water quenches thirst, food satisfies hunger, wood floats on water, iron sinks in water, and so on. From these we conclude that *Nature behaves in the same way under the same conditions.* Thus the

Uniformity of Nature is an *Induction by Simple Enumeration* derived from a large number of similar instances. The law of the Uniformity of Nature is a conclusion of an Induction per Simple Enumeration, from a large number of inductions. "We arrive at this universal law by generalisations from many laws of inferior generality." "Thus the ground of Induction is itself an Induction." (*Mill*).

Criticism .

(*i*) According to **Mill,** the Uniformity of Nature is the ground of Induction. It is the presupposition of Induction. Without belief in the Uniformity of Nature we cannot pass from the known to the unknown—from *some* to *all*. But yet he holds that the Uniformity of of Nature is itself an Induction : It is an *Induction per Simple Enumeration*. But how can the ground of Induction be itself an Induction ? This is *arguing in a circle*. The Uniformity of Nature is the ground of Induction ; and Induction (per Simple Enumeration) is the ground of the Uniformity of Nature. Induction per Simple Enumeration relies upon the Uniformitv of Nature. How, then, can it prove the Uniformity of Nature ? This is absurd ! This is called the **Paradox of Induction.**

J. S. Mill, a great logician as he was, was alive to this paradox. Yet he wanted to wriggle out of this uncomfortable position by saying that the Uniformity of Nature, which is itself derived from Induction per Simple Enumeration, can be the ground of Induction because it is derived from a *very large number* of similar instances drawn from experience from our very *childhood.*

But these facts do not add to the value of the Uniformity of Nature which is, after all, nothing but a *precarious empirical generalisation.* An induction can never be the ground of Induction,—far less an Induction per Simple Enumeration.

(*ii*) Moreover, according to Mill, an Induction per Simple Enumeration is merely *probable*, while a Scientific Induction is *certain*, because in the former we do not prove any causal connection while in the latter we do establish a causal connection. How, then, does he hold that the Uniformity of Nature, which is a mere Inductoin per Simple Enumeration. is the ground of Scientific Induction ? *How can Probability be the basis af Certainty ?*

(*iii*) Experience cannot account for the *whole* of knowledge. There are certain fundamental *presuppositions* of experience which it cannot explain. The Uniformity of Nature is the very presupposition of experience, which cannot, therefore, be derived from experience.

II. The Evolutionist view.

Herbert Spencer holds that the belief in the Uniformity of Nature was acquired by innumerable generations of our ancestors in the past from experience by generalisation or induction, but it has been *inherited* by us from them ; so that it has become *a priori*, *innate* and *instinctive* in us. We do not derive our belief in the Uniformity of Nature from experience. It is an innate idea in us.

Criticism.

This theory shifts the difficulty one step backward, but does not finally solve it. How could our ancestors

derive the idea of the Uniformity of Nature from experience by generalisation or induction? Experience can never give the idea of the Uniformity of Nature which is the very foundation and presupposition of experience. If nature were not uniform, experience of the phenomena of nature would be impossible.

III. The Intuitionist theory.

Reid, Hamilton and others hold that the belief in the Uniformity of Nature is an *innate idea*. It is *a priori*; it is prior to all experience; it cannot be derived from experience. We immediately apprehend the idea by *intuition*. Intuition is immediate apprehension by *reason*. We cannot help believing in its truth.

Criticism.

We should not hold that the idea of the Uniformity of Nature is a *full-fledged* idea in the mind even at the time of birth or in childhood. It remains in the mind as an *aptitude*, *tendency* or *disposition* which comes out or develops in course of experience. It is the *presupposition* of experience. So it can never be derived from experience. If we do not believe in the Uniformity of Nature, we cannot experience the phenomena of Nature.

7. The Origin of Belief in the Law of Causality.

I. The Empiricist view.

According to **Hume** we get the idea of causality from sense-experience. We find in our experience that one event is always followed by another event. When we observe this sequence repeatedly in our experience, these ideas are closely associated in

our minds, so that whenever we observe the antecedent we *expect* the consequent to follow. This habit of expectation grows with the repetition of experience, due to association of ideas. *There is no necessary connection between cause and effect*, but only a subjective bond of association between the ideas of the invariable antecedent (cause) and the invariable consequent (effect). Thus our idea of causality is derived by *generalisation* from particular cases of invariable sequence.

Criticism

(*i*) The idea of causality is a *universal* and *necessary* condition of knowledge. So it cannot be derived from sense-experience, since experience can never give us universal and necessary knowledge. It can give us only particular facts.

(*ii*) The idea of causality is supposed to be derived by *induction* or generalization from particular cases of invariable succession. But induction itself is based upon the Law of Causation. Hence it is *arguing in a circle* to derive causation from induction and induction from causation.

II. The Evolutionist theory.

Herbert Spencer holds that the idea of causality was derived from experience by innumerable generations of our ancestors. But it has become *innate* and instinctive in us. It was *a posteriori* to our ancestors. They derived it from experience by *generalisation*. But we have *inherited* it from them so that it has become *a priori* in us; it is prior to our experience; it is not derived by us from experience.

Criticism.

The Evolutionist theory pushes the difficulty one step backward. How could our ancestors derive the idea of causality from experience by generalisation or *induction* which is supposed to be based upon the Law of Causality ?

III. The Intutionist theory.

Reid, Hamilton and others hold that the idea of causation is an *innate idea*. The mind is born with this idea. It is stamped upon the mind at the time of birth. It is *prior* to all experience. It cannot be derived from experience.

Criticism.

The idea of causation is not a fully developed idea at the time of birth or in childhood. It remains in the mind as a *tendency*, *aptitude*, or *disposition* which comes out or develops in course of experience.

Kant holds that we cannot derive the idea of causality from experience as experience presupposes it. The idea of causality is an *a priori* notion or *category* of the understanding which is presupposed in our experience.

8. The Scientific view of Causation (the Qualitative marks of a Cause).

Carveth Read *defines the cause as "the immediate, unconditional, invariable antecedent of the effect."* Let us bring out the implications of the definition.

(*i*) The cause and the effect both are *events* or phenomena. Both of them are changes or happenings of nature. When there is a change in nature, we seek to

account for it. When there is no change, our curiosity is not excited. If there be no change, the problem of causation does not arise. We are not concerned with the cause of the universe as a whole.

(*ii*) A cause is *relative* to a given phenomenon called the effect. We are not required to investigate the cause of the universe as a whole, but only of a part of it. We select from the infinite expanse of nature any portion that is neither too large nor too small for our comprehension. A cause is a cause in relation to the effect. An effect is an effect in relation to the cause.

Here we must avoid a misapprehension. There is not in nature one set of events called causes and another set of events called effects ; but every change is both cause of the future and effect of the past. The cause and the effect are related to each other.

(*iii*) The relation between the cause and the effect is one of *succession*. The cause which explains the phenomenon or effect precedes it. The effect always follows the cause. The cause is the *antecedent* of the effect and the effect is the *consequent* of the cause. Fire precedes burning which is its effect.

But here some objections have been raised. In the first place, it is objected that the word 'cause' implies an 'effect' so that until an effect occurs there can be no cause. So the effect cannot be the consequent of the cause. They must be simultaneous.

But this is a blunder, for while 'cause' implies an 'effect' it also implies the relative futurity of the effect, and the effect implies the relative priority of the cause. (*Carveth Read*).

It has been urged that a cause and its effect are continuous—the effect is merely the modification of the cause. The cause embodies

one kind of energy, and the effect is the modification of the causal energy. But the transformation of one kind of energy into another takes *some* time however slight it may be. So the efiect must be the consequent of its cause. "But for the same reason, there is no interval of time between cause and effect since all time is filled up with motion." (*Carveth Read*).

(*b*) It has also been objected that sometimes a cause takes a very long time to produce its effect, and the effect also continues for a very long time. In such a case, the *whole* cause is not antecedent to the *whole* effect.

In such a case, we must not take the *cause as a whole* and the *effect as a whole*. We must analyse them into their moments or minute factors. Viewed as such, "the cause, taken in its moments, is antecedent througout to the effect, taken in its corresponding moments." (*Carveth Read*). In other words, the first moment of the cause is antecedent to the first moment of the effect; the second moment of the cause is antecedent to the second moment of the effect, and so on.

A cause must always *precede* the effect. "Mere succession does not constitute the causal relation. Succession may be either *variable* or *invariable*. Variable succession never inspires in us a belief in causal connection. Clouds, for example, may precede or succeed sun-rise ; and so we never regard the one as the cause or effect of the other." (*Mitra*). *Invariable succession is a mark of causation.* We regard the cause as the invariable antecedent and the effect as the invariable consequent. An invariable antecedent is always followed by an event. Thus, the stroke of a sword is taken to be the cause of the flow of blood.

(*iv*) The cause is not only an antecedent of the effect but also the *invariable* antecedent. **David Hume** defines a cause as an invariable antecedent. Any and every

antecedent cannot be regarded as a cause. To mistake a casual antecedent for a cause is to commit the fallacy of "*post hoc ergo propter hoc*" (after this, therefore, on account of this). A comet appears in the sky and a king dies. The comet should not be regarded as the king's death. Bain says: "Every event that happens is definitely connected with some *prior* event which happening, it happens, and which failing, it fails."

(*v*) But invariable succession alone does not constitute causality. If it were so, as Thomas Reid points out, night would be regarded as the cause of day, and day, of night, since the one is invariably followed by the other. But day and night are not the causes of each other; they are the *co-effects of the same cause*, *viz.*, the brightness of the sun, roundness of the earth, and rotation of the earth round its own axis. Thus, the cause is not merely the invariable antecedent, as David Hume supposed, but also the *unconditional* antecedent. A cause, according to **J. S. Mill,** is an *unconditional*, invariable antecedent.

A '*condition*' means any necessary factor of a cause; any thing or agent that exerts, impedes or deflects energy; or anything which helps, destroys, or retards the effect. Conditions are of two kinds, *viz.*, *positive* and *negative*. A positive condition is one which cannot be left out without frustrating the effect. A negative condition is one which cannot be introduced without frustrating the effect. A positive condition must be present. A negative condition must be absent. *All the conditions taken together, both positive and negative, constitute a cause. A cause, therefore, is the sum total of all conditions, positive and negative taken*

together. When, for example, a man falls to the ground through a slip of his feet, the positive conditions are the slipping of the feet, the weight of the body, *etc.*, without which there would have been no fall, and the negative condition is the absence of a support which might have prevented the man from falling.

When Mill defines a cause as an *unconditional* antecedent, he means that it is that group of conditions which, without any further condition, is invariably followed by the effect; it is the least antecedent that suffices, positive conditions being present and negative conditions being absent. An unconditional antecedent is one which does not depend upon other conditions in order to be followed by an event. In other words, it contains within itself all the necessary conditions required to bring about the effect. It is the self-sufficing antecedent of the effect.

(*vi*) A cause, in order to be the unconditional antecedent of an event, must also be an immediate antecedent. Immediacy or immediateness directly follows from unconditionality; the former is involved in the latter. A remote antecedent can never be an unconditional antecedent. "If there are three events, A, B, C, causally connected, it is plain that A is not the unconditional antecedent of C, but requires the further condition of first giving rise to B". (*Carveth Read*). A gives rise to B and B gives rise to C. A, therefore, is invariably followed by C, under the condition that A must give rise to B at first. Therefore, the remote antecedent A cannot be the unconditional antecedent of C. A cause, therefore, must always be an immediate or proximate antecedent.

Hence, Carveth Read, has defined a cause as the unconditional, invariable and *immediate* antecedent of an event. Though the immediacy of a cause is implied in its unconditionalness, it is often so important a clue to the discovery of a cause that it deserves separate mention. And immediacy, as a mark of causation, must be liberally interpreted, because our knowledge of immediacy is subject to the limitations of our perceptive powers. Thus, *antecedence, invariability, unconditionality,* and *immediacy* are the *qualitative* marks of a cause.

9. Causation viewed as Conservation of Energy (Quantitative Equality of Cause and Effect).

To complete our account of a cause, we muse consider also its *quantitative* character. *What is the bearing of the Law of Conservation of Energy on the Law of Causality?* The Law of Conservation of Energy proves the quantitative equality between cause and effect. The Law of Conservation of Energy implies the following :—

(1) The total amount of physical energy in the universe remains constant ; it can be neither increased nor decreased ; there is neither creation nor destruction of energy. Energy means the capacity for doing work. It has various forms.

(2) One form of energy may be transformed into another. For example, the molar energy may be transformed into the molecular, the physical into the chemical, the chemical into the vital, *etc.*, or heat, light, motion, electricity, magnetism, *etc.*, into one another. When there is intense friction between two pieces of wood, heat is

generated ; when there is intense heat, light is produced. Thus one kind of energy is converted into another.

(3) Though one form of energy is transformed into another, no energy is lost in the process of change ; the causal energy is *equal* to the energy embodied in the effect. Though there is change in quality, there is no change in quantity. The effect is a *modification* of the cause. It is already contained in the cause. The effect is simply the development of the cause. The effect is *implicit* in the cause. "A cause is an effect concealed ; an effect is a cause revealed."

Thus viewed in the light of Conservation of Energy, the cause is *equal* to the effect. "As to the Matter contained, and as to the Energy embodied, Cause and Effect are conceived to be *equal*. As to matter, indeed, they may be more properly called identical ; since the effect is nothing but the cause re-distributed." (*Carveth Read*). When oxygen chemically combines with hydrogen to form water, the weight of the compound is exactly *equal* to the weight of the elements combined in it. "As to energy, we see that in the heavenly bodies, which meet with no sensible impediment, it remains the same from age to age."

Carveth Read proves the *quantitative equality* between the cause and the effect on *a priori* grounds. If the cause is not equal to the effect, it must be either *always greater* than the effect, or *always less* than the effect, or *sometimes greater and sometimes less* than the effect. The last supposition is not tenable because it contradicts the Law of Uniformity of Nature. "On the first supposition, the world and all its operations would continually diminish ; and on the second, continually increase". (*Carveth Read*). But these also are contradicted by our experience. Therefore, the cause must be *equal* to the effect.

The quantitative equality of cause and effect defines and explains the unconditionality of causation. The cause is that group of conditions which, without any further condition, is followed by its effect. In other words, the cause must be *adequate* or *equal* to the effect. Thus, Mill's mark of the *unconditionality* of a cause can be adequately explained only by the quantitative equality of cause and effect. Otherwise, it remains vague and inexplicable.

10. Moving Power and Collocation.

But sometimes we find an apparent disproportion of cause and effect. A big effect seems to arise from a small cause. But in such cases, Bain advises us to analyse a cause into a *Moving Power* or *Inciting Power* and a *Collocation* of circumstances. When a spark of fire falls into a heap of jute there is a terrible conflagration. Here, the spark of fire is the moving power and the heap of jute is the collocation. If we take into account both the moving power and the collocation, we shall always find that the ordinary cause is equal to the effect. A mob orator addresses a mob and the mob breaks into a riot. The mob orator is the moving power; the mob with its smouldering passions is the collocation. Both are the cause of the riot. A man takes a small dose of arsenic and dies. Arsenic is the moving power, and his physical system is the collocation. If we take into account both the moving power and the collocation in estimating a cause, we shall find that the cause is equal to the effect.

11. Causes and Conditions.

A *cause* is an unconditional, invariable, immediate antecedent of an event. It must not depend on any

other condition, in order to be followed by its effect. It must be the self-sufficing condition of its effect. It must contain within itself all the conditions necessary for the production of the effect. A *condition*, on the other hand, is any necessary factor of a cause.

Conditions are of two kinds, *viz.*, *positive* and *negative*. A *positive* condition is that which cannot be *left out* without *frustrating* the effect. A *negative* condition is that which cannot be *introduced* without *frustrating* the effect. A *positive* condition must be *present*, and a *negative* condition must be *absent* for the production of the effect. ***All the conditions, taken together,—both positive and negative,—constitute the real cause.*** "A cause is the sum total of the conditions, positive and negative taken together." (*Mill*). A cause is "the entire aggregate of conditions or circumstances requisite to the effect." (*Bain*).

Thus, a condition is a part of the cause. It is not the whole of the cause. But ordinary people generally regard a condition, which is a *part* of the cause, as the *whole* cause. When, for example, a man falls to the ground through a slip of his feet, the slipping of the feet is a positive condition of his fall and the absence of any support is its negative condition. Moreover, there are other positive conditions, *e. g.*, the weight of the body, the height of the position, and the fragility of the human body. These also must be taken into account. All these taken together constitute the real cause of the phenomenon. But we generally regard the slipping of the feet as the cause of the fall as it excites our interest

for the time being, though it is really a condition of the phenomenon.

A cause, therefore, is the aggregate of all conditions, positive and negative taken together, positive conditions being present and negative conditions being absent. A condition is only a part of a cause.

12. The Popular View of Causation.

(1) Ordinarily people regard *one* of the conditions as the whole cause of an event. They select one of the conditions which are necessary to bring about the effect, and regard it as the cause, because it is practically the turning point at the moment and so attracts their attention. But such a *condition* is a part of the cause. Thus, the popular view of causation is an incomplete or partial view.

A man slips from a ladder and falls to the ground. The cause of the fall is said to be the slipping, because but for slipping the man would not have fallen. But, from the scientific point of view, this is *one* of the conditions. There are other conditions as well, *e. g.*, the gravitation of the earth, and the want of a support which might have prevented the man from falling. Here a *positive condition* is regarded as the cause. A man bathes in a river, goes beyond his depth, and is drowned. Ordinary people attribute drowning to the lack of knowledge of swimming. Here a *negative condition* is regarded as a cause.

Thus, from the popular or practical standpoint, we identify a *part* of the cause with the *whole* cause. But, from the scientific point of view, a cause is the sum total

of *all* conditions, positive and negative taken together, positive conditions being present and negative conditions being absent.

(2) Common people sometimes regard the *remote cause* as the real cause of an event. For example, they regard good rainfall as the cause of a good harvest, or a good University degree as the cause of success in life. But, from the scientific point of view, a cause is the invariable, unconditional, *immediate* antecedent of an event. A remote condition cannot be regarded as a real cause. It is a group of *immediate* antecedents which invariably bring about the effect without depending upon other conditions.

(3) Common people sometimes mistake a *liberating condition* for a cause. A boy turns the tap of water and water flows. So he thinks that turning the tap is the cause of the flow of water. But, in fact, it is the liberating condition of the flow of water. If the pipe were empty, turning the tap would not be followed by the flow of water.

Agent and Patient.

(4) Common people generally draw a distinction between *agents* and *patients*, and regard the former as the cause, and not the latter. A thing acting is an agent and a thing acted on is a patient.

When, for example, a spark of fire falls into gun-powder and brings about a terrible explosion, the spark of fire is regarded as the cause, and not the gun-powder. But we know that gun-powder is as important a

condition of the explosion as the spark of fire; but for the gun-powder there would not be such an explosion. The spark of fire is the *moving* or *inciting power* and the gun-powder is the *collocation.*

We cannot account for the *whole* effect if we leave the collocation out of account. And because generally we overlook the collocation as something *passive* we think the cause and the effect to be unequal. From the scientific point of view, nothing is *passive* (patient); everything is *active* (agent). In the above example, gun-powder is not passive but active; it has energy though the energy is in a dormant or *potential* condition. The spark of fire is said to be *active* because it embodies *kinetic* energy or energy in motion. The *moving* or *inciting power* illustrates patent or *kinetic* energy, while the *collocation* or the seemingly passive arrangement of circumstances illustrates dormant or *potential* energy. In nature all things are active. There are no patients or passive things in nature.

13. Plurality of Causes.

By the doctrine of Plurality of Causes we mean that the same effect may be produced by different causes *at different times.* It does not mean that several causes or conditions *co-operate* to produce an effect. For example, death may be due to cholera, small-pox, plague, burning, drowning, *etc.*, on different occasions. By Plurality of Causes we mean 'Vicariousness of Causes'. (*Fowler*). Either A *or* B *or* C is the cause of x. It is sometimes called the doctrine of 'alternative causes.'

Mill believes in the doctrine of "Plurality of causes." He says, "It is not true that one effect must be connected with only one cause, or assemblage of conditions : that each phenomenon can be produced only in one way. There are often several independent modes in which the same phenomenon could have originated. One fact may be the consequent in several invariable sequences ; it may follow, with equal uniformity, any one of several antecedents, or collections of antecedents. Many causes may produce mechanical motion ; many causes may produce some kinds of sensation ; many causes may produce death." Carveth Read puts it thus: "The same event may be due at different times to different antecedents, that in fact there may be *vicarious causes.*"

Plurality of Causes should be distinguished from the Conjunction of Causes. *The Plurality of Causes means that the same effect may be produced by different causes at different times.* Death may be caused by small-pox, or cholera, or typhoid, or burning, or drowning. Death may be produced by *one* of these causes *separately*. *The Conjunction of Causes means that many causes co-operate at the same time in order to produce an effect.* A single complex effect is brought about by different causes acting together at the same time. For example, the death due to typhoid is brought about by many factors or conditions acting jointly. In the case of Plurality of Causes the effect x is produced by A *or* B *or* C ; while in the case of Conjunction of Causes the effect x is produced by A+B+C.

Criticism.

This doctrine is to be regarded as true from the popular or practical point of view. But it cannot bear scientific scrutiny. From the scientific point of view it is not tenable.

(1) If we take the causes in a *specific* sense, we must take the effects also in a *specific* sense. The effect is not a single circumstance. Just as the Cause is a group of antecedents, so the Effect is a group of consequents. If death be regarded as due to different causes, *e.g.*, cholera, small. pox, plague, burning, drowning, *etc.*, we must regard the effects also as different from one another. We must consider the *attendant circumstances* of the effect in different cases. If we take *the effect as a whole*, the doctrine of Plurality of Causes does not seem to be true. For example, the death due to small-pox is different from the death due to other diseases, and so on. The attendant circumstances of death due to different causes are different. If we take the *whole* effect into consideration, it cannot be said to be due to different causes. When we take a *complete* view of the cause we should also take a *complete* view of the effect.

(2) If we take the effect in a *generic* sense we must also take the cause in a *generic* sense. For example, if death be regarded as a *common* effect, its cause also must be regarded as *one and the same* being *common* to all the causes of death, *e.g.*, failure of the heart. When we take a *partial* view of the effect, we should also take a *partial* view of the cause.

Thus, if we *generalise* both the cause and the effect, or if we *specialise* both the cause and the effect, the doctrine of Plurality of Causes can never be maintained. We speak of the Plurality of Causes only because we *generalise* the effect but *specialise* the cause. But we cannot do so. We must take both the cause and the effect in the

same way. So the doctrine of Plurality of Causes is untenable.

The cause is a *totality* of essential conditions. The effect is a *totality* of consequents. We should take the cause as the totality of antecedents. We should take the effect as a totality of consequents. Then we shall find that the same total effect is produced by the same total cause. But generally we take a *complete* view of the cause, while we take a *partial* view of the effect. When we regard small-pox, cholera, plague, *etc.*, as causes of death, we not only take the condition common to all these antecedents (*e.g.*, failure of the heart) as the cause, but also its attendant antecedents. So we should not regard death only as the effect, but also its attendant consequents. We should take the totality of consequents as the effect as we take the totality of antecenents as the cause. But the doctrine of Plurality of Causes appears to be true because we take a *partial* view of the effect, while we take the *complete* view of the cause. If we take a *partial* view of the effect, we should take a *partial* view of the cause also. If we consider the common consequent as the effect, we should consider the common antecedent as the cause. If we take death as the effect, we should take failure of the heart as the cause. If we take a complete or partial view of both cause and effect, we find that the same effect is always produced by the same cause. Thus Plurality of Causes is due to failure in analysis of antecedents and consequents and disappears before scientific investigation. From the scientific point of view the same cause has always the same effect and the same effect has always the

same cause ; the relation between cause and effect is strictly reciprocal.

(3) Moreover, the doctrine of Plurality of Causes is inconsistent with the definition of cause as an unconditional, *invariable* antecedent. *A* is the cause of *a*. It means that *A* must be invariably followed by *a*. It also means that *a* must be invariably preceded by *A*. Wherever *A* operates, *a* will follow. Wherever *a* is found, *A* must have operated. The causal connection between *A* and *a* may be expressed by two hypothetical propositions—(1) If *A*, then *a*, and (2) If *a*, then *A*. Thus the same cause has the same effect, and the same effect has the same cause. The causal relation is reciprocal. The sequence is invariable in both directions. The order of events is as uniform backward as forward. Hence the doctrine of Plurality of Causes is untenable.

14. Intermixture of Effects.

When several causes operate, sometimes they produce separate effects. The causes are separate and their effects also are separate. But sometimes several causes act together, and their effects blend with one another. When several causes co-operate to produce a joint effect, we have, on the one hand, **Conjunction of Causes** and, on the other, **Intermixture of Effects**. The conjunction of causes produces an intermixture of effects. Here the causes act jointly and the effects also mingle with one another.

When several causes co-operate to produce a conjoint effect, there is an Intermixture of Effects. When several

effects produced by several causes are blended together, they constitute an Intermixture of Effects. There are two kinds of Intermixture of Effects, *viz.*, (1) *Homogeneous* and (2) *Heteropathic.*

I. Homogeneous Intermixture of Effects.

An Intermixture of Effects is called *homogeneous* when the joint effect is of the *same kind* as the separate effects. The homogeneous intermixture of effects is illustrated in Mechanics and Physics. The Homogeneous Intermixture of Effects may again take two forms:—

(*i*) In the first form, the joint effect is merely the *sum* or *difference* of the separate effects without reciprocal modification. If a man carries a weight of ten seers and another weight of five seers is added to his weight, the effect will be that he will carry a weight of fifteen seers. Again, if a man carries a weight of ten seers and the weight of five seers is taken off from his weight, the effect will be that he will carry a weight of five seers. Again, if a rope is pulled in the *same* direction by two persons, the total effect will be the *sum* of the separate effects produced by each of them. But if the same rope is pulled in *opposite* directions, the joint effect will be the *difference* of the separate effects.

(*ii*) In the second form, the separate effects may act and react upon one another in such a way that the total effect is *modified* by them, and it is not a mere sum or difference of the separate effects but their *resultant.* This is illustrated in the parallelogram of forces.

II. Heteropathic Intermixture of Effects.

An Intermixture of Effects is called *heteropathic* when the joint effect is *different* in kind from the separate effects.

When several causes co-operate so that the separate effects are blended together, lose their identity, and produce a totally new effect, there is a heteropathic intermixture of effects. Here the separate effects of the causes disappear as such and produce an entirely different kind of effect. This is illustrated in chemical and physiological phenomena.

When hydrogen and oxygen combine to form water, the joint effect (*e. g.*, water) is entirely different in *kind* from the separate effects. The properties of water are quite different from the properties of hydrogen and oxygen. When a person takes certain kinds of food, digests and assimilates them, they are converted into blood, flesh, bone, *etc.*, which are entirely different in kind.

We have already distinguished Conjunction of Causes from Plurality of Causes. In the former, several causes act *jointly* and produce a *joint effect*. A + B + C jointly produce the effect x. But in the latter, several causes act *separately* and produce the effect on different occasions. A *or* B *or* C produces the effect x.

When several causes act together and produce a joint effect, we have "Conjunction of Causes," whether the intermixture of effects is homogeneous or heteropathic. Some logicians call it "Composition of Causes." Mill uses the expression "Composition of Causes" to mean only that kind of combining of causes which produces a homogeneous intermixture of effects.

15. Mutuality of Cause and Effect.

Sometimes cause and effect react upon each other. This mutual reaction of cause and effect on each other is called *mutuality of cause and effect.* For example,

industry promotes thrift, and thrift, in its turn, encourages industry: sympathy promotes co-operation and co-operation again fosters sympathy: habits of study sharpen the understanding and the increased acuteness of the understanding increases the appetite for study.

QUESTIONS

1. Explain the Uniformity of Nature and the Law of Causation, and show their relation to each other. How are they presupposed by Induction ?

2. Distinguish between the Popular and the Scientific view of Cause.

3. Distinguish the *qualitative* and *quantitative* aspects of Causation. What is the bearing of Conservation of Energy on Causation ?

4. "A cause is an unconditional, invariable, and immediate antecedent." Elucidate the statement.

5. "The Cause and the Effect must be simultaneous." Critically examine the statement.

6. What do you consider to be the ground or evidence underlying our belief in Uniformity ?

7. 'The ground of Induction is itself an Induction.' Fully discuss this.

8. What is the ultimate principle upon which inductive reasoning is based ?

9. What is the Paradox of Induction ? How would you solve it ?

10. What do you consider to be the difference between *cause* and *condition*. Give examples.

11. What is a Cause ? What is a Condition ? What is the relation of the latter to the former ? What are the different ways of viewing causation, and which of them is the most satisfactory ? (Popular view, Scientific view, Causation as Conservation of Energy.)

12. Explain the meaning of Energy and Conservation of Energy; and show the bearing of the theory on the nature of Causality.

13. What is meant by the Cause of an event? Explain the difference between the cause and the conditions of an event and distinguish between the Proximate and Remote Cause. Illustrate your meaning by examples.

14. "A cause is an effect concealed; an effect is a cause revealed." Explain this critically.

15. Give an example of the following :—

(*a*) *Post hoc ergo propter hoc.*

(*b*) Mistaking a condition for a cause.

16. What is meant by Plurality of Causes? Is it consistent with a scientific conception of Cause? Illustrate your answer by concrete examples.

17. Can an effect be produced by alternative causes?

18. Explain what is meant by (*a*) Plurality of Causes and (*b*) Composition of Causes, illustrating each answer by one example.

19. What do you understand by the 'Plurality of Causes' and the 'Mutuality of Cause and Effect'? Illustrate your answer by examples.

20. What is Intermixture of Effects? Give examples.

21. Explain and illustrate Composition of Causes and Intermixture of Effects

22. Explain and illustrate the different modes in which two or more causes combine to produce a single effect.

23. Distinguish between the Popular and Scientific view of Causation.

24. If it be true that the same cause always produces the same effect, does it follow that the same effect is always produced by the same cause? Give reasons for your answer and support it by illustrations.

25. What do you understand by Plurality of Causes? Give an example, and show that the apparent plurality is the result of incomplete analysis either of the causes or of the effect.

26. "Plurality of Causes is due to failure in analysis and disappears before scientific investigation." Explain and discuss.

27. State and explain briefly the postulates of Inductive Inference.

28. What do you understand by the Law of Causation and the Uniformity of Nature? How are the two related?

29. Explain fully the difference between the Law of Causation in Induction and the Laws of Causation (Laws of Nature) discovered by Science.

30. In what different senses may the term *cause* be used?

31. Enunciate the principle of Uniformity of Nature. Explain: 'There is not one Uniformity of Nature but many Uniformities.'

32. Explain and illustrate the following :—

(*i*) Plurality of Causes.

(*ii*) Mutuality of Cause and Effect.

(*iii*) Intermixture of Effects.

(*iv*) Counteracting Causes. (Negative conditions).

(*v*) Uniformity of Co-existence.

(*vi*) Conservation of Energy.

CHAPTER IV

THE MATERIAL GROUNDS OF INDUCTION OBSERVATION AND EXPERIMENT

1. The Necessity of Observation and Experiment in Induction.

In inductive inference, first, we ascertain facts. Secondly, we ascertain causal connections among facts. Thirdly, we enunciate generalisations. Unless particular facts are ascertained by observation and experiment, we can neither establish any causal connection nor generalise on the strength of this causal connection. So the first step in the inductive method is the collection of particular facts by observation and experiment.

In induction we pass from particular truths to a general truth. The particular truths which constitute the premises of induction are not taken for granted. They are gathered from experience in the shape of observation and experiment. Induction is concerned with material truth. It does not assume the material truth of its premises. Observation and experiment guarantee the material truth of the premises of inductive inference. They supply us with the data or premises of induction. Hence they are called the material grounds of induction. Herein lies the importance of observation and experiment in induction. Carveth Read says: **"Observation and experiment are the material grounds of induction."**

We have already learnt that observation involves *definition*, *analysis* and *elimination*. The phenomenon under investigation must be clearly defined. It is not found in isolation in nature. It is blended with other phenomena. So it should be observed under a variety of circumstances. The irrelevant factors should be gradually eliminated and the relevant factors should be isolated. Elimination and isolation can be effected by careful analysis of the given phenomena and varying the circumstances. Thus observation involves analysis of the given facts and separation of the relevant facts from the irrelevant facts. Scientific observation and experiment are controlled and regulated by a purpose. Otherwise they cannot help us in suggesting and proving a causal connection.

2. Observation.

Observation is *regulated perception* of events as they happen in nature. It is different from casual or random perception. We walk along a street and cast our eyes on houses, trees, and the like. This is random perception. It is not attentive perception regulated by any purpose. At every moment hundreds of objects produce impressions in our minds. But we do not take note of all of them. We interpret only a few impressions. Observation means attentive perception. It involves sensations or impressions produced by external objects through the sense-organs and interpretation of them. The mind is not passive in simple observation.

Observation is always *selective*. It is always determined by our *interest* and *purpose*. "The chief essential of scienti-

fic observation is the *presence of a definite purpose.*" (*Cunningham*). The purpose controls observation and narrows the field of enquiry. What we select to observe is determined by the purpose in hand. A business man, an artist, and a teacher observe different objects in an exhibiton according to their different interests.

Therefore Observation may be vitiated by a *bias* or mental prejudice. Observation is selective, and we select objects according to our interests. Our interests are different. So our observations of facts also differ. Observation is not mere reception of impressions but *interpretation* of impressions. We interpret impressions in the light of our mental predispositions. If we have a *bias* or prejudice, it is bound to affect our interpretation of impressions and vitiate our observation. A timid person mistakes a patch of moonlight for a ghost, a rope for a snake, a bush for a bear. A miser mistakes rustling of leaves for the sound of burglary. Observation consists in recording facts and interpreting them rightly. Illusions are due to the misinterpretation of the impressions received from external objects. The senses are not wrong, but the mental reactions are wrong in illusions. We should consciously free our minds from bias or prejudice.

Observation should not be mixed with *unconscious inference.* We simply observe the different positions of the sun. But when we say that the sun moves round the earth we mix observation with inference. We unconsciously infer the movement of the sun round the earth from the different positions of the sun observed. Thus sometimes observation is vitiated by unconscious inference.

Observation is sometimes made in the light of a *hypothesis*. We frame a hypothesis after observing a large number of similar facts. Then we deduce consequences from it and compare them with other facts actually observed. We verify the hypothesis by fresh observation of other facts Thus observation is guided by a hypothesis. For instance, we make a hypothesis that rat fleas are carriers of plague bacilli after ebserving many cases of outbreak of plague. Then we observe other cases of outbreak of plague where also rats die of plague. Here observation is regulated by a hypothesis. But we must not twist facts to suit our pet theory. "It is difficult to find persons who can with perfect fairness register facts for and against their own peculiar views." (*Jevons*). We should cultivate an attitude of detachment towards the hypothesis which guides our observation for the time being. We should be equally ready to give due weight to the instances which appear to negate the hypothesis as well as to those which strengthen it.

Sometimes observation is made with the help of *instruments*. The mere use of instruments does not transform simple observation into experiment. But we must not interfere with the phenomenon observed. We must not *modify* it in any way. Instruments extend the powers of the sense-organs and enlarge the range of observation. "An object too small or too distant to be seen, a sound too low to be heard, are rendered evident by microscope, telescope, or microphone."[1]

---

1. Welton and Monahan: *An Intermediate Logic*, p. 296.

Instruments increase the exactness of observation. "We can judge weight by the hand, but not with the accuracy of the balance ; we can distinguish temperature by the skin as greater or less, but not with the certainty of the thermometer."[1]

Observation should be made by a person whose experience in the field of enquiry is wide. The expert's observations are superior to those of a layman. The expert has mastered the secret of careful observation. But the layman cannot collect, isolate, and interpret the relevant phenomena. Ordinary observation should be strengthened by scientific observation. Ordinary observation analyses the concrete given whole and selects certain parts for consideration. It is liable to error in interpreting the given facts. Scientific observation goes deeper and seeks to discover deeper uniformities, more exact classifications, more comprehensive laws. It is more exact and precise and fruitful of results.[2]

3. Cautions in Observation.

Observation of facts is liable to be vitiated by (1) *physical*, (2) *physiological*, and (3) *mental* conditions.

(1) Physical conditions are such as distance, weather, clouds, rainfall, fog, etc. We cannot observe facts accurately in a bad weather. Fog and mist obstruct our vision. Distance prevents our sight. These obstacles to observation should be removed or correctly appreciated.

1 *Ibid*, p. 296.

2 Cunningham : *Text-Book of Logic*, pp. 213–14 ; *The Elements of Logic*, p. 301.

(2) Physiological conditions are the defects in our sense-organs and the body. Our hearing or vision may be defective. A short-sighted person cannot perceive distant objects distinctly. A long-sighted person cannot read a book. A jaundiced person sees everything yellow.

These factors should be taken into account in appraising the reports of the senses.

(3) Mental conditions are mental predispositions due to past experience, interest, and prejudice. Past experience produces mental habits or dispositions. We interpret impressions in the light of these dispositions. So we are liable to commit mistakes in observation of facts.

Men have different interests. They tend to make them insensible to facts that do not harmonise with their interests. Different eye-witnesses to the same event (*e. g.*, a football match) give different reports because their observations are coloured by their interests.

Prejudice or bias vitiates observation. We cannot find any good traits in the character of our enemies. And we cannot find any bad traits in the character of our friends. Scientific observation should be unbiased and dispassionate.[1]

4. Rules of Observation.

(1) We should not mix up observation with *inference*. Sometimes observation is vitiated by unconscious inference. We must not misinterpret the impressions received through the sense-organs from external objects. We should observe facts without a bias.

1 Cunningham : *Text-Book of Logic*, pp. 215–26.

(2) We should observe a *number* of cases and get the average. We should co-operate with other observers and compare notes with them.

(3) We should take note of the *material* points and should not take note of irrelevant circumstances. A physician should examine the lungs, heart, spleen, liver, stomach, and other organs of a patient, but should not care to count his teeth or measure his height.

(4) We should observe the phenomenon under investigation under *various* circumstances in order to separate the relevant and essential factors from the irrelevant and inessential factors. In order to know the effects of vaccination, we should vaccinate persons of various ages and of various localities and observe its results.

(5) We should observe the phenomenon under investigation in *isolation* from other phenomena, so far as it is possible. These rules can be better observed in experiment.

5. Experiment.

An Experiment is observation under *pre-arranged* conditions with the help of an *instrument.* In experiment we artificially produce the phenomenon under investigation and observe it minutely. In observation we cannot determine or modify the conditions under which a phenomenon occurs in nature. We must make the best of what is given to us. "It is here that experiment comes to the aid of simple observation by supplying a means of control over natural conditions. By isolation and com-

bination of physical agents it can so manipulate them as to determine in many cases the conditions under which the phenomena to be examined occur. Such definitely determined observation is what is meant by experiment.[1]

In experiment we interfere with the course of nature. For example, we observe electricity in the form of lightning, but we artificially produce it at pleasure by experiment. In observation the conditions under which events occur are presented by nature. In experiment they are controlled by us.

Bain says: "Observation is *finding* a fact; Experiment is *making* one." In observation we merely notice a fact which happens in nature, while in experiment we control the circumstances in such a way as to give rise to the phenomenon which we wish to observe. So experiment is organised and controlled observation under favourable conditions known and prepared by us beforehand so as to eliminate the irrelevant circumstances and isolate the relevant ones.

Stock says: "Observation is *passive* experience, while Experiment is *active* experience." This view is wrong. Observation is not passive experience. It does not consist in mere reception of impressions. It consists in interpretation of impressions. It involves a great deal of attention and active exertion of the mind. Observation is not passive, but active searching for a fact, guided by an idea, plan, or purpose. Experiment also is an active process of controlled observation under artificial conditions. An

---

1 *An Intermediate Logic*, p. 299.

experiment is more careful, cautious, attentive and accurate perception than simple observation.

Observation may not sometimes be guided by a hypothesis. But experiment is very often guided by a *hypothesis*. Observation of a large number of facts suggests a hypothesis which is afterwards verified by experiment. Bacon compares experiment with cross examination of a witness. In experiment we put definite questions to nature, and wring out answers from her. We provide such conditions that she is compelled to answer our specific questions.

6. The Relation of Observation to Experiment.

Observation and experiment are different degrees of *perception*. They are not different in *kind*. They differ in *degree*. Experiment is more exact and accurate and more careful than observation. Experiment is accurate observation under artificial conditions with the help of an apparatus. "The difference between observation and experiment is one, not of kind, but of *degree*. Experiment is not a distinct method of acquiring knowledge, but is rather the preparation of a phenomenon under known, instead of under unknown, conditions, and shall, consequently attain the highest possible degree of accuracy."[1] Thus experiment is a definitely determined observation rendered more accurate by an instrument. It is observation under pre-arranged conditions.

1 Welton : *Manual of Logic*, Vol. II, pp. 114-15.

Observation precedes experiment. Experiment presupposes some knowledge acquired by previous simple observation. Neither observation alone nor experiment alone is competent to discover the laws of nature. Observation should be supplemented by experiment in inductive investigation. Observation of a large number of similar facts of nature suggests a *hypothesis* which is afterwards verified by experiment. Experiments are the great instruments of *proof*, while observation is often a valuable aid to *discovery*. Hence a combination of observation and experiment is necessary for the successful investigation of natural phenomena and the discovery of the laws of nature.

7. The Purpose of Experiment.

(1) The aim of experiment is to *eliminate* the irrelevant and inessential conditions and single out the relevant and essential conditions which bring about the phenomenon under investigation. Observation cannot completely eliminate the inoperative conditions, because the phenomena in nature are inextricably blended with one another. "Appeal to experiment is necessary whenever simple observation alone will not make plain all the essential conditions of a phenomenon; and its object is to eliminate all conditions which are not specially operative in the particular case under consideration."[1]

(2) The aim of experiment is to *test a hypothesis* suggested by previous observation. Observation of a large number of facts suggests a hypothesis that air vibration is the cause of sound. This hypothesis is established by ex-

1 *An Intermediate Logic*, p. 301.

periments. We ring a bell in the air and hear its sound. But if we ring the bell in a vacuum from which air has been rigidly excluded, we do not hear a sound. These experiments verify the hypothesis.

(3) The aim of experiment is also to discover facts upon which hypotheses may be built and laws of nature may be discovered.

8. Different Kinds of Experiments.

(1) Positive Experiment.

A positive experiment is one in which both the phenomenon under investigation and its cause are *present.* It deals with a *positive instance* of the phenomenon, in which it occurs. If *A*, then *a*. This is a positive instance of *a*. If we inoculate comma-shaped bacilli into a healthy rabbit, it is attacked with cholera. This is a positive experiment. This is a positive instance of cholera. It shows that a particular cause produces a particular effect.

2. Negative Experiment.

A negative experiment is one in which both the phenomenon under investigation and its cause are *absent.* It deals with a *negative instance* of the phenomenon, in which it does not occur. If *A* is *not*, *a* is *not.* This is a negative instance of *a*. We ring a bell in a vacuum from which air is completely eliminated. It does not produce sound. This is a negative instance of sound. It shows that in the absence of a particular cause (*e.g.*, vibration of air) a particular effect (*e.g.*, sound) is absent.

(3) Natural Experiment.

Sometimes nature provides us with a *special* instance in which a phenomenon is observed *under special conditions.* It is beyond our control. We cannot artificially reproduce it by experiment. It is a rare and *exceptional* phenomenon supplied by nature. For instance, the eclipse of the sun or the moon is a natural experiment. On such an occasion astronomers take advantage of the rare phenomenon and make observations with telescopes.

9. Advantages of Experiment over Observation.

(1) **Multiplication of Instances.**—In experiment we can *multiply* the instances of a phenomenon as often as we like. Here we have control over conditions under which the phenomenon is reproduced. So we may repeat experiments as often as we like. Observation, on the other hand, fails to give us a sufficient number of instances. Nature does not provide us with a sufficient number of instances of a phenomenon. For example, we can produce electricity by experiment as many times as we like. But we cannot observe flashes of lightning as many times as we like. Likewise we cannot observe a comet or an earth-quake many times.

(2) **Sufficient Variation of Circumstances.**—In experiment we sufficiently *vary* the circumstances of the phenomenon under investigation and observe its different behaviour in each case. But in observation we cannot study a phenomenon under a sufficient variety of conditions. Here we have to depend entirely upon the

bounty of nature. "It is only by the use of experiment that instances can be sufficiently varied in the points of identity and difference to show clearly and simply what the essential conditions are. And these can often be determined with a quantitative precision." (*Welton*).[1] For instance, by experiment we chemically combine nitrogen with oxygen in various proportions, produce various kinds of oxides of nitrogen and observe their properties. But nature does not provide us with these varieties of nitrogen oxides.

(3) **Sufficient Isolation of Relevant Circumstances.**—Experiment enables us to *isolate* the relevant circumstances from the irrelevant ones. Under artificial conditions we can effectively eliminate the irrelevant and inoperative conditions and observe what essential conditions are operative in the production of a particular phenomenon. Observation, on the other hand, often fails to *eliminate* all the irrelevant antecedents so as to isolate the particular antecedent we want to isolate. For example, we want to discover what element in the air supports combustion. Is it oxygen or nitrogen ? Nature does not separate the two elements from each other. By experiment we produce oxygen and nitrogen. We put a burning stick first into a jar of nitrogen and it is extinguished. Then we put a burning stick into a jar of oxygen and it burns more brightly. Thus we know that oxygen supports combustion.

(4) **Circumspect perception.**—Lastly, in experiment we observe the phenomenon under investigation with

1 *An Intermediate Logic*. p. 300.

greater coolness and circumspection. We cannot observe a flash of lightning coolly and accurately. But when we produce electricity in the laboratory, we can coolly and precisely observe its properties. If we want to observe the nature of an earth-quake, we cannot do so when it occurs because it practically disapppears when we become fully alive to it. Carveth Read says, "Experiment enables us to observe coolly and circumspectly and to be precise as to what happens, the time of its occurrence, the order of successive events, their duration, intensity and extent."[1] The advantages of experiment over observation are the limitations of observation.

10. Advantages of Observation over Experiment.

(1) Observation is *wider* in scope than experiment. There are certain phenomena which are beyond our control. We cannot make experiments upon the heavenly bodies, the winds and tides, the strata of the earth, the evolution of the species, and the movements of history. Again, there are certain agencies too dangerous to experiment with. A physician cannot experiment with human life to try the effect of a deadly poison. A statesman cannot create anarchy to watch its effect upon the people. In the study of human life and social and political phenomena we have to depend upon observation. "The geologist, in tracing the history of the earth, is confined to observation as to the structure and formation of rocks and the occurrence of fossils ; the biologist is unable to experiment on the evolution of the species ; the historian cannot experiment

1 *Logic*, 4th edition, p. 200.

with the past. On other grounds the doctor and the politician are limited in the experiments it is permissible to make."[1]

(2) Observation enables us to reason *from the effect to the cause* as well as *from the cause to the effect.* But experiment enables us to reason from the cause to the effect and not from the effect to the cause. When we are required to find out the cause of a given effect by experiment, we adopt a round-about method; first, we hit upon a hypothetical cause and make experiment with it in order to find out if it produces the given effect. If it does produce the given effect, it is regarded as the real cause. In experiment we cannot reason directly from the effect to the cause. If we inject poison into an animal it dies. Here we proceed from the cause to the effect. But if an animal is dead, we cannot compel death to reproduce its cause. We cannot invert the course of nature. Observation, on the other hand, enables us to proceed both from the cause to the effect and from the effect to the cause. We find out the cause of malaria among its antecedents. We discover that anopheles mosquito bite is the cause of malaria. And we find out the effect of anopheles mosquito bite among its consequents. We discover that malaria is its effect.

(3) Observation precedes experiment. Experiments are possible only when we have already acquired some knowledge of the phenomenon under investigation by simple observation. Experiment presupposes observation.

1 *An Intermediate Logic*, pp. 300—301.

Observation suggests a hypothesis which is verified by experiment. Advantages of observation are the limitations of experiment.

11. Observation and Explanation.

Observation and experiment supply particular phenomena of nature. They should be classified into different kinds according to their similarities and differences. Then they should be explained by general laws of nature. First they suggest hypotheses which, when verified, become laws of nature. When particular facts have been examined by the methods of observation and experiment, and their qualitative and quantitative aspects have been precisely determined, we should try to establish causal connections among them and discover their laws. "Complete knowledge demands an *explanation* of the facts as determined by the methods of observation. The scientist is not content to know merely *that* such and such phenomena happen in certain definite ways, but he attempts to discover *why* this is so."[1] Particular phenomena are explained by general laws. These laws are explained by higher laws. Thus observation and experiment lead to explanation.

Creighton rightly points out that observation and explanation go together. When we say that in scientific investigation we should first observe and describe the facts as accurately as possible and then proceed to explain them by theories and laws, we make an artificial separation between collecting and describing the facts, and relating or explaining them. "Both processes go on simultaneously. The observation of instances presupposes some

1 *An Introductory Logic*, p. 252.

guiding idea, some provisional hypothesis, perhaps held in the mind as a question to be answered. We discover the relevant facts as we go along with our investigation, just as we discover the appropriate conception or explanation. And just as the facts observed and described involve theories and conceptions, so the explanation to which we proceed is simply a fuller and more accurate description."[1] We should remember the close relation between observation and explanation, and yet should not miss the distinction between them. The nature of particular facts is ascertained by observation, while their causal relations are ascertained by explanation.

12. Testimony.

We can observe a small fraction of facts that occur here and now. And yet we accept many facts as true that happen in distant parts of the earth, and that happened in the past. Our knowledge of history and geography depends upon our belief in the *testimony* of others. Testimony is not an independent source of knowledge. It involves *perception* and *inference*. Historical events were actually observed and recorded by certain persons. Their accounts were sifted and critically examined by many historians of unquestioned integrity and high intellectual capacity. Therefore we infer that the historical events described by them must be true. If the accounts of different historians are conflicting, we should exercise our judgment and discrimination. Even as to the truth of contemporary events not personally

1 *An Introductory Logic*, pp. 246—47.

observed by us, we have to depend upon the testimony of others. When the testimony of different persons as to the same event is conflicting, we should examine it carefully in order to arrive at truth. The value of testimony is liable to be vitiated by the following factors :—

(1) The perceptions of persons might be vitiated by defects in the sense-organs, a bias or mental prejudice, self-interest, sympathy or antipathy. Perceptions might be mixed with unconscious inference. Their perceptions might be wrongly recorded owing to their inaccurate expressions.

(2) The testimony of persons may be vitiated by their errors of memory. We cannot remember every thing we perceived. We very often fill up the gaps of memory by imagination unconsciously. This is why we find discrepancy among the reports of reliable persons.

(3) The source of information of the persons on whom we rely may itself be indirect and may be erroneous.

We should make allowance for all these sources of error in the testimony of others. We should critically examine and sift the evidence of others and appraise its correct value. We should not uncritically accept the testimony of others.

13. Observational and Experimental Sciences.

There are certain phenomena which do not lend themselves to experimentation. We cannot experiment with them. For example, we cannot experiment with heavenly bodies, weather, rocks and fossils. It is

dangerous to experiment on human life. It is equally dangerous to experiment with social, political and historical phenomena in the human society. So we have to depend entirely upon observation to study these phenomena. Therefore, Astronomy, Geology and Meteorology are observational sciences. In Physiology experiments are possible only on a limited scale because the phenomena of life are extremely complex and delicate. Civics, Politics, History, Sociology, Economics, in fact, all social sciences are observational sciences. They cannot make use of experiments.

Mechanics, Physics and Chemistry are experimental sciences. Mechanical, physical and chemical phenomena lend themselves to experimentation. They can be easily investigated and measured quantitatively by experiments. So Mechanics, Physics and Chemistry are experimental sciences which are more exact and accurate than observational sciences like Civics, History and Politics. Experimental sciences are most advanced sciences.

Mellone observes: "Without experiment Mechanics, Physics and Chemistry could scarcely exist, and these are fundamental sciences in an advanced state. In Physiology, experiment naturally plays a much smaller part; for, if made, at all, it has to be made on the organs of the living body. In the sciences of description and classification,—Botany, Zoology, Minerology,—the range of experiment is still more restricted; while in Astronomy, Geology, Meteorology, we may say that experiment is impossible."[1]

---

1 *Logic*, pp. 293—94.

14. Fallacies of Observation.

Fallacies of observation are of two kinds, *viz.*, Non-observation and Mal-observation. Non-observation is failure to observe relevant facts. Mal-observation is wrong observation.

(1) **Non-observation.**—This consists in overlooking or neglecting facts or instances which ought to have been observed. Observation is selective. In making this selection we may overlook either negative instances or operative conditions. Non-observation is committed in these two ways :—

(i) Neglect of Negative Instances.

When we take account of positive instances and overlook negative instances, we commit the fallacy of non-observation. Bacon said long ago that there is in the human mind a peculiar tendency to dwell on the positive and to overlook negative instances. We are impressed by the occurrence of an event, but omit to take note of its non-occurrence. The belief in the prophetic character of dreams is based upon the neglect of negative instances in which dreams are not fulfilled. When we are carried away by the predictions of astrologers and fortune-tellers, we are impressed by those which come true, but fail to notice those which prove false. When we are impressed by the success of a young lawyer or a doctor in a few cases, we neglect those cases in which he fails. In these cases, we do not take note of negative instances and commit the fallacy of non-observation. *Inductions by Simple Enumeration* are vitiated by non-observation.

(ii) Neglect of Operative Conditions.

Sometimes we fail to take note of all the *material* circumstances that are operative in the production of a phenomenon. In sociology, politics, economics, etc., the subject-matter is extremely complex. So the essential conditions that are actually responsible for a phenomenon escape our notice, and we commit the fallacy of non-observation. For instance, a decrease in the number of convictions for drunkenness does not necessarily prove a decrease in the number of public houses or of the crime itself, because such decrease may be due to other causes, *e. g.*, special legislation, vigilance of the police or the municipality, etc. "Owing to the complexity of the phenomena, all inductions connected with social and economic subjects are particularly liable to this form of fallacy." [1]

"The most extreme case of non-observation is the invalid inference that because a phenomenon has never been observed it is necessarily non-existent." [2] Non-observation is not proof of non-existence. Argon was not observed for a long time as a constituent of the air. So it was thought to be non-existent.

(2) **Mal-observation.**—This consists in *wrong* observation or *misinterpretation* of the things perceived. It consists in wrong interpretation of sense-impressions. It consists in mistaking one thing for another. When, for example, we mistake a rope for a snake, a patch of

1 *An Intermediate Logic*, p. 308.

2 *A Manual of Logic*, Vol. II, p. 263.

moonlight for a ghost, a post for a man, etc., we commit the fallacy of mal-observation. To regard the tricks of a magician as real facts of experience is a familiar instance of this fallacy. Mal-observation gives rise to illusions. In illusions the senses are not wrong, but mental reactions are wrong.

QUESTIONS

1. Elucidate—"Observation and Experiment are the material grounds of Induction".

2. What are the respective advantages (*a*) of Observation over Experiment and (*b*) of Experiment over Observation ?

3. 'Observation and Experiment do not differ in *kind* but only in *degree*'. Explain this remark.

4. 'Observation is finding a fact and Experiment is making one.' Discuss the statement fully.

5. Explain the nature of Observation and Experiment and their places in Induction. How does Experiment supplement Observation ?

6. Define Observation and Experiment, giving examples of each. Explain why the processes require treatment in Inductive Logic. What are the advantages of the latter over the former ? What sciences depend mainly on Observation and why ? What sciences depend mainly on Experiment and why ?

7. Induction derives its premises from Observation and Experiment. Describe and exemplify these two processes, showing clearly the difference between them. In what does the superiority of Experiment, as a source of premises, consist ?

8. What do you understand by elimination ? 'Observation and Experiment are aids to elimination.' Explain.

9. How are Observation and Experiment related to each other ? Bring out their importance in Induction.

10. "Experiment is always preferable to Observation." Why is this? Explain with examples from any science how observation and experiment supplement each other.

11. In what exactly does the fallacy of mal-observation consist? Give an example.

12. To what extent do (*a*) unintentional inference, and (*b*) selective interest, enter into ordinary observation? What precautions must be taken in scientific observation to avoid error?

13. Distinguish between Observation and Experiment and indicate the main sources of error in each.

14. Explain and illustrate the following :—

(i) Mal-observation.

(ii) Natural Experiment.

(iii) Negative instance.

15. Name and explain by examples some of the important errors incident to observation.

16. What are the common errors of observation?

17. Do hypotheses assist observation in any way? If so how?

CHAPTER V

HYPOTHESIS

1. The Necessity of Hypothesis in Induction.

Induction is an inference from particular facts to a general law. It is a reasoning from a few observed cases to all similar cases. It involves a passage from the known to the unknown. We pass from the known to the unknown because we believe in the Uniformity of Nature and the Law of Causation. These are the formal grounds of induction. Observation and experiment supply us with particular phenomena. We can read a general law out of them when we prove a causal connection between the two phenomena about which we want to make a universal statement. But before we can discover and prove a causal connection, we must suspect a causal connection after observing a large number of instances. Observation and testimony furnish particular facts. The mind interprets them by determining their relations to one another. At first, it makes a supposition to account for the facts. Every supposition we make as to the cause of an event is called a hypothesis. It is a provisional explanation of a phenomenon. A supposition as to the cause of an event based on some evidence is called a hypothesis.

The causal investigation may take two forms. First, the cause may be given and we may be required to find out its effect. Secondly, the effect may be given and we may be required to find out its cause. The former is com-

parativeiy an easy task. But the latter is a difficult one. We cannot compel an effect to reproduce its cause, for it would be inverting the course of nature. So here we adopt a round-about method. First, we try to hit upon a probable cause or a *hypothetical cause* by a stroke of imaginative insight after observing a large number of similar facts, and then try to find out if the effect produced by the hypothetical cause actually tallies with the effect in question. If it does tally, the hypothetical cause is the real cause. If it does not tally, we substitute another hypothesis and try to find out if it is the real cause. Herein lies the importance of hypothesis in induction. Sometimes we have to frame a hypothesis also as to the effect of a given cause. To frame a hypothesis is to suspect a causal connection, and without proving a causal connection between the ground of inference and the inferred property there cannot be an induction. Thus the framing of hypothesis is a preliminary step in inductive investigation. When a hypothesis is verified by the experimental methods, it becomes an induction. Thus Hypothesis is subsidiary to Induction.

2. Relation of Hypothesis to Induction.

In regard to this question there is a controversy between Mill and Whewell. According to Dr. Whewell induction is mainly concerned with *discovery*. According to him the process of framing a hypothesis after observing a large number of facts is the most essential step in inductive investigation. Induction, according to him, consists in making one hypothesis after another in order that we may ultimately hit upon the right hypothesis by which we can explain all the facts under investigation. Mill, on the

other hand, holds that Logic is essentially concerned with *proof*. The framing of a valid hypothesis is a preliminary process in induction. It must be verified by the experimental methods. A hypothesis is a mere conjecture or a supposition, though it is based on the observation of a large number of facts. But it can never be regarded as an induction unless it is proved by the experimental methods. According to Mill, the employment of the experimental methods is the most essential step in inductive investigation.

Dr. Whewell over-estimates the importance of hypothesis and under-estimates the importance of the experimental methods, while Mill over-estimates the importance of the experimental methods and under-estimates the importance of hypothesis. But we must remember that the experimental methods can be applied only when a hypothesis has already been framed. An inductive investigation is not an aimless act but a systematic procedure to prove or disprove a hypothesis already framed. And we must also notice that a mere hypothesis unverified by the experimental methods can never be regarded as an induction. Thus, both hypothesis and experimental methods are indispensably necessary for induction.

3. Nature and Definition of Hypothesis.

A hypothesis is an attempt at explanation. It is a supposition made in order to explain certain facts. "A hypothesis is a supposition or assumption of a cause or a law, made on an inadequate evidence, to explain some natural phenomena. Mill defines a hypothesis thus: An *hypothesis* is any *supposition* which we make (either without

actual evidence, or on *evidence* avowedly insufficient) in order to endeavour to *deduce* from it conclusions in accordance with facts which are known to be *real*; under the idea that if the conclusions to which the hypothesis leads are known truths, the hypothesis itself either must be, or at least is likely to be, true."

Mill's definition implies the following steps :—

(1) **Observation.**—A Hypothesis must be based on *observation* of a number of facts resembling one another in essential features. It must be based on some evidence, either adequate or inadequate. It cannot be a guess without any foundation in facts. It must be based on some evidence.

(2) **Framing of a Hypothesis.**—A Hypothesis is a *supposition* made by cognitive *imagination*. It is a guess or conjecture as to the probable cause of a phenomenon. Logic cannot teach one to frame a hypothesis. It depends on a stroke of imagination. It depends on one's insight and natural gift. The sight of an apple falling to the ground suggested to Newton the hypothesis of gravitation.

(3) **Deduction.**—We must *deduce* consequences from the hypothesis in order to see whether they tally with actual facts or not. If the consequences tally with facts, the hypothesis is true or is likely to be true. But if its consequences do not tally with facts, it should be discarded in favour of another hypothesis.

(4) **Verification.**—Thus a hypothesis is verified by deduction and observation. We must compare the consequences deduced from a hypothesis with the *facts*

under investigation in order to *verify* it. If the consequences tally with the facts under investigation, the hypothesis is verified and we accept it to be the real cause.

4. Different Kinds or Forms of Hypotheses.

There are three kinds of Hypotheses, *viz.*, hypotheses as regards an *Agent*, the *Law* of its operation, and the *Collocation*. A hypothesis is framed to explain a phenomenon. To explain a phenomenon is to find out its *cause* and the *law* of its operation ; and if both the cause and the law of operation are known, we assume the *collocation* or combination of circumstances under which the cause operates. Thus, a hypothesis may be framed about a *Cause*, its *Law* of operation, or a *Collocation*.

(1) **Hypothesis about an Agent or Cause.**—When the law of operation is known to us, we may assume an unknown *Agent* or *Cause* to explain a certain phenomenon. A theft is committed in my house. I am quite sure of theft. My room is broken open, my cash box is broken, and my money is removed. Now, I make a guess as to the person who has stolen my money. Here I make a hypothesis as regards an agent. Ether is supposed to account for the phenomena of light. Undulation of ether is said to be the cause of light. Here we make a hypothesis concerning an agent. Again, in order to explain some deviations observed in the movements of Uranus, another planet (*a new agent*) was supposed to exist in a particular position, which operating according to the known law of gravitation caused these deviations. Here, the law of operation, *viz.*, garvitation was already known.

So the new *Agent*, *viz.*, Neptune was assumed to exist. And this hypothesis was verified when Neptune was discovered with a powerful telescope. Again, nitrogen in the atmosphere was found to be slightly heavier than pure nitrogen produced in the laboratory. This was supposed to be due to the presence of some other gas in the atmosphere. It was later discovered to be argon. These are examples of hypotheses about agents.

(2) Hypotheses about a Law.

When the cause or agent is known to us, we assume a *law* or mode of its operation. For instance, a theft is committed in my house. My stolen goods are found in the house of a suspected person. So I make sure of the agent. But I do not know *how* he committed the theft. I guess how he made his way into my room, and broke open my cash box and decamped with my money. Here I make a hypothesis as regards the mode of operation. Again, the agents, *viz.*, the Earth, the Moon, the Sun and other heavenly bodies were already known to us. But what was the Law according to which these agents operated so that there were motions of the planets, was not known to us. So the hypothesis was made that their motions might be due to their attracting one another, or to the law of gravitation. The different species of animals were known to exist, but how they were connected with one another was not known. Darwin made a hypothesis that complex species were evolved out of simpler species according to the Law of Natural Selection. He made a hypothesis concerning a Law.

(3) Hypothesis about a Collocation.

When both the cause and the law of its operation are known to us, we frame a hypothesis as regards the collocation or definite arrangement of circumstances under which the cause operates. For instance, a theft is committed in my house, I know the thief and the way in which he stole the money. But I do not know under what collocation of circumstances he committed theft. I make a supposition as to the collocation. Again, the Earth, the Moon, Mars, the Sun and other heavenly bodies were known ; and their law of operation also, *viz.*, gravitation was known. So a hypothesis was made as to the *collocation* of the heavenly bodies ; in Ptolemaic Astronomy, the Earth was regarded as the centre of the heavenly bodies, while in Copernican Astronomy, the Sun was regarded as the centre of the universe. The former hypothesis has been proved to be true.

Thus, "a Hypothesis may be made concerning (1) an Agent, such as the ether ; or (2) a collocation. such as the plan of our solar system—whether geocentric (the earth as the centre) or heliocentric (the Sun as the centre) ; or (3) a Law of an agent's operation, as that light is transmitted by wave-motion." (*Carveth Read*).

An agent and collocation together constitute a cause. So some logicians recognize two kinds of hypotheses as regards a Cause and a Law.

5. Origin of Hypothesis.

There are no general rules for making hypotheses. It depends upon creative genius. Men differ much in their

power to frame hypotheses. The man of scientific genius is fertile in suppositions, but he must have a wide knowledge of facts.

There are certain circumstances which favour discovery. They are as follows :—

(1) Induction by Simple Enumeration.

We frame a hypothesis after observing a large number of similar facts. It is based on some evidence, adequate or inadequate. A general conclusion based on uniform or uncontradicted experience is called an Induction by Simple Enumeration. For instance, finding that scarlet flowers are devoid of fragrance in a large number of cases, we frame a hypothesis that all scarlet flowers are devoid of fragrance. Thus, an *Induction by Simple Enumeration* is a source of discovery.

(2) Conversion of Propositions.

Simple conversion of an **A** proposition, though invalid suggests a hypothesis. The simple conversion of the proposition "All men are mortal" may lead us to the hypothesis—"All mortals are men." It may be put to test, and accepted or rejected. This hypothesis is wrong. There are other animals that are mortal. All plants also die. These facts lead us to the right hypothesis—"All living organisms are subject to death." Hence the simple conversion of affirmative universal propositions always suggests a new hypothesis, *i. e.* points out the possibility of a new relation whose actuality must be solved by a new process of enquiry."[1]

1 *A Manual of Logic*, Vol. II, p. 64.

(3) Analogy.

Analogy also is often a source of discovery. It is a kind of incomplete induction. It is an inference from known particulars to an unknown particular. It is based on imperfect resemblance between two things. Whenever we find that two things are similar in some respects, we are led to believe that they are also similar in certain other respects.

We find that the Earth and Mars resemble each other in certain respects, *viz.*, atmosphere, temperate climate, clouds, land, water, etc., which are conducive to life, and also find that the Earth is inhabited by living beings. So we conclude that Mars also may be inhabited by living beings. Thus, analogy is a source of hypotheses.

(4) The Method of Agreement.

When we find two phenomena conjoined in a number of instances,—other circumstances varying,—we conclude that there may be a causal connection between them. We find a large number of instances in which female anopheles mosquitoes bite healthy persons of different ages, having different occupations, living in different places, and they suffer from malaria. So we conclude that female anopheles mosquitoes may be carriers of malaria bacilli. This hypothesis may be verified by experiment. Thus the Method of Agreement suggests Hypotheses.

(5) The Method of Concomitant Variations.

When we find that two phenomena *vary* concomitantly (*i. e.* together)—the other circumstances remaining

the same—we suspect a causal connection between them. When we find that the greater the number of liquor shops in a locality, the greater the number of crimes, we suspect a causal connection between drunkenness and criminality. The greater the quantity of armaments piled in different countries, the greater the possibility of a war. So we suspect a causal connection between the two phenomena. Thus the Method of Concomitant Variations suggests Hypotheses.

(6) The Method of Residues.

The Method of Residues also is often a source of discovery. When the greater part of a complex phenomenon is explained by some causes already known, we try to explain the residual part of the phenomenon according to the known law of operation. Some deviations were found in the movements of Uranus. They could not be accounted for by the attraction of the known heavenly bodies. So a new planet was supposed to exist in a particular position, whose attraction explained the deviation. And such a planet was actually discovered later and was called Neptune. The nature of these Experimental Methods will be discussed later.

6. The Conditions of a Legitimate or Valid Hypothesis.

A hypothesis is a guess as to the cause of a phenomenon. But any guess or supposition is not a legitimate or scientific hypothesis. It must conform to certain

conditions in order to be regarded as a **legitimate hypothesis.** The conditions are the following :—

(1) **A hypothesis must not be absurd and self-contradictory.**—If a person is missing, we should not suppose that he has evaporated or has been taken away by spirits or angels. The more reasonable hypothesis is to suppose that he has suddenly left for some other place, or committed suicide, or been decoyed and murdered. To account for earthquake by supposing that a huge bull takes the earth from one horn to another to support it is absurd. To account for the eclipse of the sun or the moon by its being swallowed by a huge monster called Rahu is absurd. To account for rainfall by the sprinkling of water by an enormous elephant from the sky is absurd. All these hypotheses are absurd and extravagant in the light of modern knowledge. Such popular hypotheses are due to complete ignorance of science.

It is self-contradictory to suppose that the same cause produces different effects under the same conditions. So a hypothesis should not be absurd and self-contradictory.

(2) **A hypothesis must be definite and verifiable.**—It should not be vague and indefinite. A vague hypothesis cannot account for any phenomenon. If earthquake is said to be due to *some* disturbance in the interior of the earth, it is a worthless hypothesis. We should define the *nature* of the disturbance; otherwise it cannot explain the phenomenon. The so-called invoking of spirits by table-rapping is a vague and indefinite hypothesis. Therefore it cannot be regarded as a legiti-

mate hypothesis. A hypothesis must admit of verification; it must be either proved or disproved. Neither of the hypotheses can be put to test and proved or disproved. So they are worthless from the scientific point of view.

A hypothesis must be of such a nature that consequences may be *deduced* from it and compared with actual facts. Creighton says: "An hypothesis from which nothing can be deduced is of no value whatever, for it is entirely incapable either of proof or disproof. The essential requirement is that something should be *deducible* from the hypothesis, that it shall lead somewhere, and thus afford a programme for further investigation. In general it is possible to deduce the consequences of a theory only when the principle employed is *analogous*, in mode of operation, to something with which we are familiar. Thus, for example, it is because *ether* is conceived as resembling other material bodies in important respects that in can be used as a principle of explanation. It is assumed to be elastic and capable of receiving and transmitting vibrations, and as spread out like other material bodies in space. In virtue of these similarities to other material substances it is possible to deduce the consequences which such a substance as ether would imply, and to compare them with the actual facts. But if one should make the assumption that certain phenomena are due to some agency totally unlike anything of which we have any experience, a disembodied spirit, or ghost, for example, it would be impossible either to prove or disprove the assertion."[1]

1 *An Introductory Logic*, pp. 340—41.

A hypothesis must be verifiable, and in order to be verifiable it must be made definite. If it is not definite at first, attempts should be made to make it definite. Carveth Read regards definiteness and verifiability only as conditions of a legitimate hypothesis. He says, "To be verifiable, an hypothesis must be definite ; if somewhat vague in its first conception (which is reasonably to be expected), it must be made definite in order to be put to the proof. But, except this condition of *verifiability*, and *definiteness* for the sake of verifiability, it seems inadvisable to lay down rules of a 'legitimate' hypothesis."[1] But other logicians lay down two other conditions of a valid hypothesis.

(3) **A hypothesis must have for its object a vera causa (real cause).**—If the hypothesis refers to an agent or cause, it should be a *vera causa.* Newton says, "only *veræ causæ* (real causes), are to be admitted in explanation of phenomena." The agent assumed to exist must be a *vera causa.* A *vera causa* is an agent that can be directly perceived, and if it is imperceptible by its very nature (*e. g.*, ether) it must be reasonably believed to be existing, and must not involve self-contradiction. In other words, it must be based on facts or deductions from it should agree with real facts. It should be based upon some evidence gathered from experience. Ghosts, spirits, witchcraft, etc., are not *veræ causæ.*

Carveth Read says : "If a new agent be proposed, it is desirable that we should be able directly to observe it, or at least to obtain some evidence of its existence of a different kind from the very facts which it has been

1 *Logic*, p. 270.

invented to explain. Thus, in the discovery of Neptune, after the existence of such a planet outside the orbit of Uranus had been conjectured (to account for the movements of the latter), the place in the heavens which such a body should occupy at a certain time was calculated, and there by means of the telescope it was actually seen."[1]

(4) A hypothesis must not conflict with the known Laws of Nature.—"Every hypothesis is an attempt to relate observed phenomena, to known laws. It follows that the fundamental condition of a valid hypo-pothesis is that it should explain the facts of observation. And it can only do this if it relates isolated facts to orderly systems of facts."[2] The hypothesis must be self-consistent, and in harmony with known laws. Knowledge is a system. Its various parts are inter-related with one another. Some laws have already been established after elaborate investigation. So, if a new law is supposed to account for certain phenomena, it must not contradict any of such well established laws. If a law is proposed in Physics, which contradicts the Law of Gravitation, we should look upon it with suspicion. If a law is proposed in Chemistry, which contradicts the Law of Definite Proportions, it cannot be regarded as a legitimate hypothesis. If a law is proposed in Biology, which disregards the Law of Heredity, it cannot be taken as a valid hypothesis. But all these conditions of a valid hypothesis should be interpreted liberally. All the new laws of great significance proposed by scientists

1 *An Intermediate Logic*, p. 329.

2 *Logic*, pp. 270—71.

were slowly accepted by others and the people. Harvy's Law of Circulation was not accepted by old men because they could not break the inertia of their habits of thought.

7. Proof of Hypothesis.

A hypothesis is a provisional or tentative supposition to explain certain facts. It must conform to certain conditions in order to become a legitimate hypothesis. When a legitimate hypothesis conforms to the following conditions it becomes an *established* hypothesis :—

(1) **A hypothesis must be adequate to account for all the phenomena under investigation to explain which it has been invented.**

We frame a hypothesis to explain certain phenomena. If they cannot be explained by the hypothesis, it does not serve any useful purpose. Therefore, the hypothesis must *adequately* explain all the phenomena under investigation. For example, if we frame the hypothesis of the Andulation of Ether to explain the phenomena of light, it must adequately explain all the phenomena of light. In fact, it is adequate to explain all the phenomena of light. Newton's Corpuscular theory of light was not adequate, and therefore it was discarded in favour of the undulatory theory of light.

But here we must make certain observations :—

In the first place, a hypothesis takes some time to explain all the phenomena under investigation. So, a hypothesis should not be rejected hastily without trying it for some time. It may be modified in the light of experience.

Secondly, a hypothesis should account for all the phenomena *so far as it professes to.* It may not explain other phenomena which it does not profess to. It is no objection to the theory of the origin of species, that it does not explain the origin of life, for it does not profess to do so. It proposes to explain how different species of animals have come into existence.

"Thirdly, a hypothesis originally intended to account for the whole of a phenomenon and failing to do so, though it cannot be established in that sense, may nevertheless contain an essential part of the explanation. Inadequacy, therefore, is not a reason for entirely rejecting a hypothesis or treating it as illegitimate."[1] (*Carveth Read*).

(2) **A hypothesis must not only be adequate to explain all the phenomena under investigation, but it must also be unconditional.**

A hypothesis must be the only hypothesis to explain some phenomena. If certain phenomena can be explained by more than one hypothesis equally well, we must decide between the conflicting claims of rival hypotheses. A scientific hypothesis must preclude the possibility of rival hypotheses. We should not unnecessarily multiply the agencies required to explain the phenomena under investigation. This is known as the *Law of Parsimony.*

Crucial Instance: Experimentum Crucis.

But how can we decide between the conflicting claims of rival hypotheses? This can be done by discovering

[1] *Logic*, pp. 274—75.

a **Crucial Instance** which at once terminates the conflict between contending hypotheses. If such a case is obtained by experiment it is called an **Experimentum Crucis.** For example, the fact of the aberration of light is a decisive instance which supports the Copernican, instead of the Ptolemaic system of Astronomy. So it is a crucial instance. "Before Galileo's experiment at Pisa, it was supposed that bodies fell to the ground with a velocity proportional to their weight ; Galileo maintained the opposite hypothesis, *i. e.* that the weight of bodies was irrelevant to the rate at which they fell. By dropping cannon balls of *unequal* weight from the top of the leaning tower at Pisa and observing that they reached the ground at the *same* time, he proved his hypothesis. Such an experiment is called an *Experimentum Cruois*."[1]

"A crucial instance not only *confirms* one hypothesis but *negatives* the other." (*Jevons*). The term is borrowed, as Bacon says, from the crosses (or finger-posts) which are put up at the junction of many roads pointing the way to be taken. "A crucial instance serves as a sign-post, to point out the direction of truth."

(3) Consilience of Inductions.

It means the quality which a hypothesis possesses of explaining facts other than those which it claims to explain.

"A hypothesis must agree with the rest of the Laws of Nature ; and, if not itself of the highest generality, must

---

1 *An Intermediate Logic*, p. 334.

be derivable from primary laws." "*A hypothesis must be in harmony not only with the facts which it undertakes to explain but also with facts known in other departments of Nature.* The more a hypothesis tends towards unity, harmony, or consistency, the stronger is the evidence in its favour." (*Carveth Read*). For instance, we find that the theory of gravitation not only explains the falling of bodies to the earth, but also explains the ebb and tide, the movements of planets, etc. So it is proved better still. Whewell lays stress on this proof. Mill attaches no weight to it. Carveth Read holds that consilience of inductions is not a sufficient proof of the truth of a hypothesis.

(4) Prediction, according to Whewell, is one of the proofs of a hypothesis.

If a hypothesis can predict facts which prove true, it is proved. "Astronomers predict eclipses long beforehand with the greatest precision."

Yet Mill pointed out that a predicted fact is only another fact, and if a hypothesis happens to agree with many *known* facts, it may also agree with some *unknown* fact. It is not something extraordinary. As a matter of fact, many false hypotheses lead to predictions which come true. For example, Ptolemaic Astronomy, though false, predicted solar and lunar eclipses which actually happened. Hence prediction cannot be regarded as a test of a valid hypothesis.

(5) The most essential condition of the proof of a hypothesis consists in its Verification.

A hypothesis is verified by an appeal to actual facts. We start from facts to arrive at a hypothesis. And we

verify a hypothesis by appealing to facts. *Verification* of a hypothesis may be either *direct* or *indirect*. It may be directly verified by *observation* or *experiment*. Or it may be indirectly verified by *deduction* or *accumulation of facts* consistent with the hypothesis.

Carveth Read beautifully sums up the conditions and proofs of a legitimate hypothesis. "A hypothesis must, to deserve the name in science, be *verifiable* and therefore, *definite* and to establish itself as a true theory, it must present some symptom of *reality*, and be *adequate* and *unconditional* and *in harmony with the system of experience*."[1]

8. Different Modes of Verifying a Hypothesis.

(1) A hypothesis may be verified by direct **observation**. When, for example, the existence of a planet at a certain distance was assumed to exist to account for some deviations in the path of Uranus, the hypothesis was verified afterwards by telescopic observation, and the planet was called Neptune.

(2) A hypothesis may be verified by **induction** or **experimental methods.** If we can artificially reproduce the effect under investigation by experiment, a hypothesis may be verified in this way. When, for example, the assumption that cholera is the effect of comma-shaped bacilli is verified by inoculating a healthy rabbit with the bacilli and producing the disease, the hypothesis is proved to be true. Here the hypothesis is verified by experiment.

1 *Logic* p. 280.

(3) A hypothesis may be verified by **deduction.** For example, the law of terrestrial gravity is verified when it is deduced from the higher law of attraction. All hypotheses are verifiable more or less by deduction. We deduce consequences from a hypothesis and then try to find out if they tally with the effect under investigation. For example, the assumption that planetary motions are produced by their projectile tendencies and gravitation, was deductively verified, when the results mathematically deduced from these laws were actually found to correspond with the observed motions of different planets.

(4) A hypothesis is sometimes verified by **uncontradicted experience.** If a hypothesis cannot be verified either by direct observation or experiment, or by deduction or inductive methods, we have to depend entirely upon our uniform or uncontradicted experience. Almost all the empirical laws are hypotheses of this type.

9. Working Hypothesis, Tentative or Provisional Hypothesis, Descriptive Hypothesis and Explanatory Hypothesis.

A hypothesis with which we start to explain certain phenomena under investigation is called a **Working Hypothesis,** for we assume it to be adequate for the time being. It is also called **Tentative or Provisional Hypothesis.** It is provisionally adopted with some evidence in its favour to explain certain phenomena under investigation, and it serves as a guide to further investigation in a certain direction. It is a starting-point for investigation and is subject to verification by observation

and experiment. Thus, the Ptolematic theory of Astronomy was a *working* hypothesis which prepared the way for the Copernican theory of Astronomy. And the Corpuscular theory of light was a *working* hypothesis which prepared the way for the Undulatory theory of light.

We make a hypothesis as to the *cause* of a phenomenon or the *law* of its happening. It either refers to an *agent* or to a *law* or mode of operation. A *Hypothesis of Cause* is called an **Explanatory Hypothesis** because it seeks to explain certain phenomena. A *Hypothesis of Law* is called a **Descriptive Hypothesis** because it seeks to describe the manner in which the phenomena occur. The former explains *why* certain phenomena occur. The latter describes *how* they occur. An explanatory hypothesis explains a phenomenon by assuming a cause or agent, while a descriptive hypothesis assumes and describes the law of its operation.

10. Representative Fictions.

"Some Hypotheses," says Bain, "consist of assumptions as to the minute structure and operations of bodies. From the nature of the case, these assumptions can never be proved by direct means. Their only merit is their suitability to express the phenomena. They are **Representative Fictions.**" For example, the phenomena of light are explained by the vibration of ether ; the assumption as to the existence of ether, which can never be directly perceived, is a Representative Fiction. Jevons calls it a **Descriptive Hypothesis.**

11. Hypothesis and Theory.

A well-established hypothesis is called a theory. Thus we speak of the theory of gravitation, not of the *hypothesis* of gravitation. Thus, the modern hypothesis regarding the origin of light is called the Undulatory *Theory* of light as it is confirmed by a large number of instances. When a hypothesis is proved beyond the shadow of doubt by direct Observation or Experiment or Deduction from a higher law, it is called a **Law**. When, for example, the existence of Either will be established by observation or experiment or deduction from a higher law, the Undulatory Theory of light will be established as a Law. At the present stage it is called a theory. But the distinction between hypothesis and theory is a delicate one. The proof which may be considered as adequate to theory by some may be considered as insufficient or inadequate by others of a sceptical turn of mind. Thus, what would be called a hypothesis by some would be called a theory by others.

12. Hypothesis and Fact.

By '**facts**' we mean concrete events or phenomena. A hypothesis is called upon to explain particular facts which are objects of our experience. A hypothesis is general and abstract, while facts are concrete and particular. From *particular* facts of experience we reach a *general* hypothesis to explain them. Sometimes by facts we mean not the particular events of nature and mind, but *general truths*. In this sense, a hypothesis becomes a **fact or a law** when it is proved by the experimental methods. A theory whose truth is established is accepted as a Fact.

13. Hypothesis and Explanation.

The function of a hypothesis is to *explain* certain phenomena. For example, to explain the phenomena of light the Corpuscular theory of light was proposed by Newton. This was found to be inadequate to explain all the phenomena of light. So, now the Undulatory theory of light has taken the place of the Corpuscular theory of light. To explain a phenomenon is to find out its cause and its law of operation. But we cannot discover them all of a sudden. Sometimes we have to adopt a roundabout method. We have to hit upon a probable cause or law to explain the phenomenon under investigation. This is called a hypothesis. Then the hypothesis is to be tested by further investigation. Thus, a *hypothesis* is the starting point of the discovery of a cause or the law of its operation to *explain* certain phenomena.

14. The Uses of Hypothesis.

The framing of a hypothesis is an indispensable preliminary in scientific investigation. Without some provisional or working hypothesis we cannot direct our investigation in a definite line. All the established laws of science were mere hypotheses in the beginning. When they were verified they became laws. Bacon did not recognise the importance of hypothesis in inductive investigation. He said that we should not "anticipate nature." Observation will yield Laws of Nature. Newton's assertion "**Hypotheses non fingo**" (I do not make hypotheses) was directed against rash conjectures or random and unwarranted hypotheses. No scientific investigation is possible

without a hypothesis. Newton himself framed the *Corpuscular* hyphothesis of light which was afterwards replaced by the *Undulatory* theory. And his law of gravitation was after all a hypothesis. Thus, it is clear that no scientific investigation is possible without a hypothesis. The uses of hypothesis may be stated as follows:—

(1) A hypothesis systematizes *knowledge*. We *colligate* or bind together many particular facts by a *hypothesis* which is subsequently verified by facts. Many phenomena are explained by a hypothesis. They are reduced to a unity by the hypothesis.

(2) A hypothesis *leads to discovery*. In all scientific investigations we must start with a hypothesis. When it is completely verified it amounts to discovery. Thus, the existence of a planet which might account for the deviations in the path of Uranus was started as a hypothesis which afterwards led to the discovery of Neptune.

(3) Even if a hypothesis does not lead to any actual discovery, it offers explanation which makes the *unknown* phenomena *intelligible* and thus satisfies the curiosity of the mind.

(4) *It is the starting-point of Induction.* In inductive investigation we start with a hypothesis and then try to verify it by the experimental methods. A hypothesis makes the application of the experimental methods possible.

(5) Even when a hypothesis is disproved by further investigation, it serves a useful purpose by paving the way for a true hypothesis. In the absence of a better hypothesis

a provisional hypothesis will serve our purpose for the time being.

(6) A hypothesis, though based on observation and experiment, guides our further observation and experiment. "Inductive investigation is not a random procedure, but a well-regulated course, controlled by the dominant idea of a hypothesis, which determines the line of observation and experiment." (*A. C. Mitra*). If a hypothesis is thrown out after close enquiry, we adopt another hypothesis which again controls our observation and experiment. In this way we proceed until we hit upon the right hypothesis which can adequately account for all the phenomena under investigation.

QUESTIONS

1. Explain the function of Hypothesis in Induction. Give a critical exposition of the views of Mill and Whewell on this point.

2. Distinguish between Colligations and Inductions. Are all Colligations to be regarded as Inductions ?

3. Distinguish between (*i*) a working hypothesis and an established hypothesis, and (*ii*) a valid induction and a legitimate hypothesis.

4. What are the different ways of verifying hypotheses ?

5. Write short notes on the following :—

'*Hypotheses non fingo*', representative fictions, *vera causa*, descriptive hypothesis, working hypothesis, *experimentum crucis*, legitimate hypothesis, and crucial instance.

6. What is a Hypothesis ? It is said that all induction depends upon hypothesis. How far is this true ? When can a hypothesis be said to be established ?

7. Distinguish between a Working Hypothesis and a Descriptive Hypothesis.

8. What are the different forms of Hypothesis ?

9. What are the circumstances favourable to discovery ?

10. Explain how Hypotheses contribute to scientific discovery.

11. Give examples of (*a*) Hypothesis about unknown agent, (*b*) hypothesis about the mode of operation of known agent, (*c*) verifiable hypothesis.

12. When is a Hypothesis said to be valid ?

13. What are the characteristics of a legitimate hypothesis ?

14. Give the canons to which a good hypothesis must conform.

15. How does a legitimate hypothesis differ from a Scientific Induction ? Give illustrations.

16. State and explain the essential conditions of a valid Hypothesis.

17. What are the chief requisites of a valid hypothesis ?

18. What seems to you a satisfactory proof of a hypothesis ?

19. What constitutes a valid Induction ? Distinguish it from a legitimate hypothesis.

20. Given a verifiable hypothesis, what constitutes proof or disproof ?

21. Distinguish between a Working Hypothesis and an Established Hypothesis.

22. Distinguish between a Working Hypothesis and a Legitimate Hypothesis.

23. What are the uses of Hypothesis ?

24. Explain and distinguish—Hypothesis, Theory and Fact.

CHAPTER V

THE EXPERIMENTAL OR INDUCTIVE METHODS

1. The Nature of the Experimental Methods.

Scientific Induction seeks to discover a general law of nature from particular phenomena observed. It can do so by discovering and proving a causal connection. And to discover a causal connection, very often we have to fame a hypothesis. Thus, the framing of a hypothesis is a preliminary step to induction. But a hypothesis is a mere supposition; it is based on inadequate or insufficient evidence. So, it must be put to the proof; and it is proved by the Experimental Methods. The Experimental Methods are the instruments by which we prove a hypothesis or a suspected causal connection. They are devices for establishing a causal connection between any two phenomena by the elimination of irrelevant or inessential circumstances and the isolation of relevant or essential ones. Thus the Experimental Methods are the weapons of elimination. They are mainly methods of *proof*. But sometimes they are mainly methods of *discovery* also. They generally test hypotheses. But sometimes they also suggest hypotheses.

The Experimental or Inductive Methods are five in number, *viz.*, (1) Method of Agreement, (2) Joint Method, (3) Method of Difference, (4) Method of Concomitant Variations, and (5) Method of Residues. These Methods were formulated by John Stuart Mill.

2. The Inductive Methods as Weapons of Elimination.

The Inductive Methods prove a causal connection by eliminating the irrelevant or accidental circumstances from the relevant or essential ones. Unless the casual and inert conditions are excluded we cannot find out the causal and potent conditions. But the *elimination* of the accidental circumstances with a view to the *isolation* of the essential ones depends on the **variation of circumstances**. The phenomena of the world are inextricably blended together into a complex tissue. In every instance of a phenomenon there are many antecedent and many consequent circumstances. We should *analyse* the complex phenomenon into its simple components, and distinguish its antecedents, consequents, and collateral events. Then in order to prove causal connection, we must try to find out what are the inert or accidental factors and what are the potent or material factors. We can isolate the causal or essential conditions from the casual or inessential conditions by following the Baconian method of **varying the circumstances** or studying a phenomenon under a variety of conditions.

So, the Inductive Methods have been described by Bain as **Weapons of Elimination**. But this description is partially true. The Inductive Methods are devices for not only excluding or *eliminating* the accidental circumstances but also for selecting or *isolating* the causal or material circumstances. The function of the Inductive Methods is not merely *negative* but also *positive*. Their function is not mere negative *exclusion* of irrelevant factors

but also positive *selection* of relevant factors. Their main function is to isolate the essential and invariable conditions of a phenomenon which are really operative, and in order to do so, they have recourse to the exclusion or elimination of variable and inessential conditions. Hence it is inappropriate to call the Experimental Methods purely methods of *elimination*.

3. The Inductive Methods as Deductions from Causation: Principles of Elimination.

The Inductive Methods are based on the Law of Causation. They are based on certain principles which are deduced from the Law of Causation. A cause, from the scientific point of view, is the invariable, unconditional, and immediate antecedent of the effect, and, taken quantitatively, is equal to the effect as to the matter and energy embodied. From these qualitative and quantitative marks of a cause three principles have been deduced which are the basis of the Inductive Methods. These causal principles are as follows :—

(1) "Whatever antecedent *can be left out* without prejudice to the effect, can be no part of the cause."[1] (*Bain*).

A cause is the *invariable* antecedent of the effect. Consequently, the effect cannot be produced without the presence of the cause. If the cause is left out, the effect must disappear. "A cause is what produces an effect. As the presence of the cause is the presence

1 *Logic: Induction*, p. 47,

of the effect, so the absence of the cause is the absence of the effect. The absence of the cause with the presence of the effect, would be a contradiction of the law. We are sure, therefore, that whatever can be omitted or withdrawn without making any difference to the effect in question, is not the cause, or any part of the cause. If we cut a string that we suppose to be the support of a weight, and the weight continues to be supported, the string is not the support."[1] The Method of Agreement is based on this causal principle.

(2) "When an antecedent *cannot be left out* without the consequent disappearing, such antcedent must be the cause or a part of the cause." (*Bain*).

A cause is the invariable antecedent of the effect. From the invariable connection between the cause and the effect, it follows that so long as the cause continues the effect must continue, and as soon as the cause disappears the effect also must disappear. This causal principle presents the other side of the same invariable connection of cause and effect; the absence of the cause is the absence of the effect. "Whatever, by disappearing, makes the effect to disappear, is by that very fact an essential or causal condition. If the cutting of a string is the falling of a weight, the string is the support of the weight."[2] The Method of Difference is based on this causal principle.

1 *Ibid.* pp. 47—48.

2 *Ibid*, p. 48.

This causal principle follows from the *quantitative equality* of the cause and the effect. Viewed from the stand-point of Conservation of Energy, the cause is *equal* to the effect. Consequently, if the cause increases or decreases in quantity, effect also must increase or decrease in quantity. So, when two phenomena vary in *numerical concomitance i. e.* increase or decrease together proportionately, they must be causally connected. For example, the greater the heat the greater the expansion, the greater the cold the greater the contraction ; so they must be causally connected. The Method of Concomitant Variations is based on this causal principle.

Thus, the Method of Agreement, the Method of Difference, and the Method of Concomitant Variations are based on the above three canons deduced from the Law of Causation. The Joint Method is an extension of the Method of Agreement. And the Method of Residues is a modification of the Method of Difference. So, all the five Inductive or Experimental Methods are deductions from the Law of Causation. Some of them are methods of *discovery*, while others are methods of *proof.* Some are used to establish the *causal connection* among phenomena, while others seek to determine the *quantitative* aspect of the causal relation. Some are *qualitative* methods, while others are *quantitative* methods. Now, let us consider these five methods separately in detail.

(3) "An antecedent and a consequent rising and falling together *in numerical concomitance* are to be held as Cause and Effect."[1] (*Bain*).

1 *Ibid.* p. 48.

4. The Method of Agreement or the Method of Single Agreement.

(1) Its object.

The object of this method is to eliminate all antecedents except one in order to show that so long as one particular antecedent continues, a particular consequent follows.

(2) Its Canon.

"*If two or more instances of a phenomenon under investigation have only one other circumstance (antecedent or consequent) in common, that circumstance is probably the cause (or an indispensable condition) or the effect of the phenomenon, or is connected with it by causation.*" (*Carveth Read*).

"If several instances of the occurrence of a phenomenon agree only in one thing, that thing is probably the cause." (*Stock*).

(3) The Basic Principle.

The Method of Agreement is based upon the following principle of causality. Whatever antecedent can be left out without prejudice to the effect, or whatever antecedent can be present without the effect being present cannot be its cause or part of its cause.

(4) Symbolical Example.

A B C followed by *p* q r

A D E..................*p* s t

A R S..................*p* u v

∴ *A* is the cause of *p*.

Here, p is the phenomenon under investigation; A B C D E R S are the antecedent circumstances; *A* is the circumstance in common. *A* is the common antecedent, and p is the common consequent. B C D E R S are variable antecedents; they are not present in all the instances. Hence, they cannot be the causes of p. The common antecedent *A* is the cause of the common consequent p; or they are causally connected. Here we require a number of *positive* instances of the phenomenon under investigation, which agree only in one common antecedent,—other antecedents and consequents varying.

(5) Concrete Examples.

(*a*) *From effect to cause:—*

(1) We observe many persons suffering from malarial fever. They live in different places, take different kinds of food, wear different kinds of clothes, pursue different occupations, and belong to different strata of society. They are bitten by anopheles mosquitoes. This is the only common antecedent of malarial fever. Other antecedents, *e. g.*, places, food, clothes, occupations, etc., are variable; they are present in some instances and absent in others. So the anopheles mosquito-bite is the cause of malarial fever.

(2) Heat expands a bar of iron; it also expands a bar of silver, it expands a bar of copper; it expands a bar of brass; it expands a bar of lead. Here there is one common antecedent, *e. g.*, expansion. All other antecedents are variable. Various metals are heated. They are not always present. So heat is the cause of expansion.

(3) Heat converts gold into a liquid. Heat converts silver into a liquid. Heat converts copper into a liquid. Heat converts brass into a liquid. Heat converts lead into a liquid. Again, heat converts these liquids into gases. Here the common antecedent is heat. The common consequent is the conversion of a solid body into a liquid, or conversion of a liquid into a gas. So heat is the cause of conversion of solids into liquids, and of liquids into gases.

(4) We dissolve common salt in water and evaporate the water. It assumes crystalline structure. We dissolve sugar in water and evaporate the water. It assumes crystalline structure. We try many other substances which assume crystalline structure in the same manner. Here the substances vary. But there is only one common antecedent, *viz.*, solidification of a substance from a liquid state. Therefore it is the cause of crystallization.

(5) States that make war their chief object assume a certain type of military organisation. They develop the growth of a warrior class and treat labourers as slaves to the warriors. They completely subordinate individuals to the will of the despotic soldier-king or dictator. Their property, liberty, and life are at the service of the State. Freedom of speech and association is suppressed. This was the case in Sparta, in Egypt, in the empire of Yncas. This is the case in Fascist Italy, Nazi Germany, and Soviet Russia. But the similarity of organisation in the States cannot be due to race, for they are of different races; nor to the size, for some are small, some large; nor to climate or other geographical conditions which differ

widely. The one common antecedent is the military purpose. This, therefore, must be the cause of their military organisation[1].

(*b*) *From cause to effect :—*

(6) We want to find out the effect of the contact of an alkaline substance with oil. We try various combinations of alkaline substances with different kinds of oil. They resemble each other in nothing else. The result in every case is the formation of soap. Therefore we conclude that the production of soap is the effect of the combination of an alkaline substance with an oil. (*Mill*).

(7) We want to find out the effect of drinking carbolic acid. We observe that John, a young, white, wealthy banker drinks carbolic acid and dies. Smith, an old, coloured, poor barber drinks carbolic acid and dies. Woo Choo, a middle-aged, yellow carpenter of moderate circumstances, drinks carbolic acid and dies. The cases differ in all respects except one. Drinking carbolic acid is the common antecedent of death. So it is the cause of death.

This method is called "**The Method of Agreement**," because it requires a number of *positive* instances of a phenomenon, which *agree* only in one other circumstance. They contain only one common antecedent. They differ in all circumstances. Hence the common antecedent and the common consequent are supposed to be causally connected. This method is also called "**The Method of Single Agreement.**"

---

1 Carveth Read ; *Logic*, p. 211.

(6) The Uses of the Method.

(*i*) The Method of Agreement is pre-eminently a *method of observation.* Where experiments are possible, we employ the Method of Difference. Where experiments are not possible, we employ the Method of Agreement. Where the phenomena under investigation do not lend themselves to experimentation, they should be investigated by the Method of Agreement. It does not require instances of a special character which presupposes exact knowledge. The Method of Difference, on the other hand, requires instances of a special character which cannot be supplied by observation. Hence the Method of Agreement is chiefly a method of observation. This does not mean that it cannot be applied to cases where experiments are possible.

(*ii*) The Method of Agreement is a method of *discovery* as well as of *proof.* It *suggests* a hypothesis which is verified by the Joint Method or the Method of Difference. It is a method of observation. We cannot control the phenomena under investigation. So we cannot conclusively prove causal connection by this method. It does no more than strengthen a hypothesis of causal connection.

(*iii*) It is "the universal or fundamental mode of proof for all connexions whatever." (*Bain*). It proves all kinds of uniformities, whether of *co-existence* or of *succession.*

(*iv*) The Method of Agreement is a method of observation. So it can find out the cause of a given effect and also the effect of a given cause. The concrete examples

given above illustrate this point. Observation enables us to proceed from an effect to its cause as well as from a cause to its effect.

(7) The Defects of the Method of Agreement.

(1) The Method of Agreement is vitiated by the possibility of **Plurality of Causes.** This is its characteristic imperfection. In the symbolical example, B or C might be the cause of *p* in the first instance, D or E might be the cause of *p* in the second instance, and R or S might be the cause of *p* in the third instance, and A might be accidentally present all along. For instance, a doctor cures a fainting fit with whisky and soda; another doctor cures a fainting fit with brandy and soda. Another doctor cures a fainting fit with wine and soda. Here soda should not be regarded as remedy for a fainting fit. In the first case whisky is the cause of cure ; in the second brandy is the cause of cure ; in the third, wine is the cause of cure. Soda is accidentally present in all the cases. Similarly, a person takes castor oil with water and removes his constipation. Another person takes cascara with water and removes his constipation. Another person takes magnesium sulphate with water and removes his constipation. Here, water, the common antecedent, is not the cause of the removal of constipation. The variable antecedents are causes in different instances. Therefore the Method of Agreement is liable to be frustrated by the possibility of Plurality of Causes, which may be taken as true only from the practical point of view.

Counteraction of Plurality of Causes.

(*i*) The defect due to Plurality of Causes may be overcome partially by *multiplication of instances.* If we observe a large number of instances and find that one circumstance is present in all of them, the conclusion is irresistible that it is causally connected with the phenomenon under investigation. If we find very many cases of the event *a* preceded constantly by A, it becomes almost certain that the connection between A and *a* is causal rather than accidental. The greater the number of instances observed, the greater the probability of the conclusion in the Method of Agreement.

(*ii*) The defect arising from Plurality of Causes is completely remedied by the Joint Method. The Joint Method is an extension of the Method of Agreement. Here there is a set of positive instances as well as a set of negative instances. The positive instances suggest a hypothesis which is proved by the negative instances. The antecedents that might be the causes in the positive instances appear in the negative instances, but they are not followed by the effect in question. Therefore they cannot be its causes. Thus the Joint Method completely removes the defect arising from Plurality of Causes.

(2) The Method of Agreement cannot distinguish between cases of *co-existence* and those of *causation.* Wherever there is the sea, there is the sky. But the sea is not the cause of the sky. Ruminating animals are cloven-footed. But ruminancy is not the cause of cloven-footedness. They may be co-existent. Or they may be co-effects of the same cause not yet known.

The Method of Agreement cannot distinguish between *cause* and *effect* and the *co-effects* of the same cause. For example, sleeplessness and headache, which often accompany each other, may be the co-effects of the same cause, *viz.*, overwork or worry. Day and night are invariably followed by each other. But neither of them is the cause of the other. They are the co-effects of the same cause.

(3) The Method of Agreement is frustrated by the Intermixture of Effects. In the symbolical example, A B C may *jointly* produce *a* in the first instance, A D E, in the second instance, and A R S, in the third instance, so that the common antecedent A cannot be regarded as the cause of *p*. The Method is based on the assumption that an effect is produced by only *one* cause and is not an intermixture of effects due to the co-operation of many causes. If the effect *p* is mixed up with *q* and *r* in the first instance, with *s* and *t* in the second instance, and with *u* and *v* in the third instance, it is difficult to say which effect is due to which of the causes. In a case of fever which has headache, nausea and pain in the joints many causes may co-operate and their effects cannot be observed separately, but in a complex joint effect. Thus the Method of Agreement is liable to be frustrated by the Intermixture of Effects.

(4) The Method of Agreement, being a method of observation, often *fails to eliminate all the irrelevant circumstances except one* because of the complexity of the phenomena. It is very difficult to analyse all the conditions of a political revolution, an economic depression, or a complicated disease, and to eliminate all the variable and

irrelevant antecedents. So it is difficult to find out the cause or effect of such complex phenomena by employing the Method of Agreement. This method requires instances which have only one common circumstance. But some other circumstance may be present in all the instances, but may not be observed. And this unobserved circumstance may be the cause of the phenomenon under investigation. This practical imperfection can be overcome, to some extent, by the multiplication of instances. If we observe a large number of instances, we are practically certain that all necessary circumstances will come to our notice. But we cannot be absolutely certain of this, because nature does not lend itself to a complete *analysis* of circumstances and does not provide a sufficient *variety* of circumstances. Therefore the Method of Agreement yields a *probable* conclusion ; and the probability increases with the *number* and *variety* of instances.

5. Distinction between the Method of Agreement and Induction by Simple Enumeration.

Both Method of Agreement and Induction by Simple Enumeration are based upon an examination of a number of *positive* instances. Both are built upon *observation* of particular facts. But Induction by Simple Enumeration is based upon mere *enumeration* or counting of instances, while the Method of Agreement is based upon *elimination* of irrelevant circumstances. In the Method of Agreement we eliminate the irrelevant antecedents and isolate the relevant ones, while in Induction by Simple Enumeration no attempt is made to eliminate the accidental circum-

stances and isolate the essential ones. The inference, here, proceeds on the ground that since two phenomena have always been found together without any exception, they will always be found to be so connected. Induction by Simple Enumeration, therefore, is less conclusive than the Method of Agreement, because there is no such rigorous elimination and isolation in the former as in the latter.

There is an essential difference between Induction per Simple Enumeration and the Method of Agreement. The former depends merely on the *number* of instances. The latter depends on the *character* and *variety* of instances. Fowler observes: "The Method of Agreement is a method of *elimination*, selecting some and rejecting other instances, and founding its conclusion not on the quantity but on the character of the instances which it selects. The *Inductio per Enumerationem Simplicem*, on the other hand, depends for its validity on the *number* of the instances." Welton and Monahan observe: "The method of agreement resembles simple enumeration in its reliance on *number* of instances, but it differs from it in the stress laid on *variety* in the accompanying circumstances."[1] "All buttercups are plants, and all buttercups contain chlorophyll (green colouring matter in plants); but I might examine a million buttercups, and on the question whether all plants contain chlorophyll, I should remain precisely where I was when I examined half a dozen. But if I examine a buttercup leaf, a blade of grass, a fern, a moss, a volvox, and a protococcus, my six

1 *An Intermediate Logic*, p. 353.

observations will give me a fair right to generalise. Normally, plants contain chlorophyll." (*Hobhouse*).

6. The Joint Method or the Method of Double Agreement.

(1) Its Object.

The Joint Method is specially designed to remove the difficulties arising from the possible Plurality of Causes, which frustrates the Method of Agreement.

(2) Its Canon.

"*If (1) two or more instances in which a phenomenon occurs have only one other circumstance (antecedent or consequent) in common, while (2) two or more instances in which it does not occur (though in important points they resemble the former set of instances) have nothing else in common save the absence of that circumstance—the circumstance in which alone the two sets of instances differ throughout (being present in the first set and absent in the second) is probably the effect, or the cause, or an indispensable condition of the phenomenon.*" (*Carveth Read*).

"Whatever is present in numerous observed instances of the presence of the phenomenon, absent in observed instances of its absence, is probably connected causally with the phenomenon." (*Mellone*).

This method is called the Joint Method of Agreement and Difference or the Method of Double Agreement. It requires two sets of instances—positive and negative—illustrating Agreement in presence and Agreement in absence. It is also called the Method of Exclusions.

(3) The Basic Principles.

The Joint Method is based upon two principles.

(*i*) Whatever antecedent can be left out without prejudice to the effect cannot be a cause or a part of the cause.

(*ii*) Whatever antecedent cannot be left out without prejudice to the effect must be a cause or a part of the cause.

(4) Symbolical Example.

Agreement in Presence. (*Positive Instances*).	Agreement in Absence. (*Negative Instances*).
*A*BC followed by *p* qr	BCD followed by qrs
*A*DE ,, ,, *p* st	DEF ,, ,, stx
*A*RS ,, ,, *p* uv	RST ,, ,, uvy
∴ *A may be* the cause of *p*.	∴ *A is* the cause of *p*.

This Method implies the double application of the Method of Agreement, *viz.*, Agreement in *presence* and Agreement in *absence*. It is applied to a set of *positive* instances in which only one antecedent is uniformly present. Then it is applied to a set of *negative* instances in which only that antecedent is absent. In the set of positive instances. *A* is uniformly present among the antecedents, and *p* is uniformly present among the consequents. The positive instances *suggest* the conclusion that *A* is the cause of *p*. In the set of negative instances, *A* is uniformly absent among the antecedents and *p* is uniformly absent among the consequents. The negative instances *confirm* the conclusion that *A* is the cause of *p*. The negative instances

prove that the variable antecedents, B, C, D, E, R, S, in the positive instances cannot be the causes of *p*, because they are present in the negative instances while the effect *p* is absent. Thus, the set of positive instances establishes a *probable* causal connection between *A* and *p*, while the set of negative instances *confirms* this conclusion by excluding the possibility of Plurality of Causes. The Joint Method differs from the Method of Agreement in having a set of negative instances, in addition to a set of positive instances.

(5) The Requirements of the Joint Method.

The requirements of the Joint Method are (1) a set of positive and a set of negative instances, (2) that both sets be drawn from the same field and be as like one another as possible, (3) that the instances making up each set be as diverse as possible.

(6) Concrete Examples.

(1) I always suffer from indigestion when I eat a certain fruit. I never suffer from indigestion when I do not eat this fruit. Therefore I conclude that the eating of this fruit is the cause of my indigestion.

(2) In whatever battles Napoleon was personally present, they resulted in successes. In whatever battles he was not personally present, they resulted in failures. Therefore, successes of Napoleon were largely due to the force of his personality.

(3) Whenever quinine is administered, malarial fever is cured. Whenever quinine is not administered, malarial

1 *The Elements of Logic*, p. 337.

fever is not cured. Therefore, the use of quinine is the cause of the cure of malaria.

(4) Whenever we find that a particular plant (*e.g.*, rice) invariably grows on a particular soil (*eg.*, low land with sufficient rain-fall) and we do not find it growing on any other soil (*e. g.*, high land with scanty rain-fall), we conclude that the particular soil is favourable to the growth of the plant.

(5) We find that dew is deposited on the objects which radiate heat rapidly. We also find that dew is not deposited on the objects which agree in nothing but the absence of rapid radiation. We, therefore, conclude that rapid radiation of heat is the cause of the formation of dew.

(6) "Darwin, to show that cross-fertilisation is favourable to flowers, placed a net about 100 flower-heads, and left 100 others of the same varieties exposed to the bees; the former bore no seed, the latter nearly, 3000. The net did not screen the flowers from light and heat sufficiently to affect the result."[1] (*Carveth Read*).

(7) "Tyndall, to prove that dispersed light in the air is due to motes, showed by a number of cases (1) that any gas containing motes is luminous ; (2) that the air in which the motes had been destroyed by heat, and any gas, so prepared as to exclude motes, are not luminous. All the instances are of gases, and the result is: motes—luminosity; no motes—no luminosity."[2] (*Carveth Read*).

1 *Logic*, p. 214. 2 *Ibid*, p. 214.

(8) Sir John Lubbock's experiments on the sense of smell in ants illustrates the Joint Method. "He took a large ant and tethered her on a board by a thread. When she was quite still, he brought a tuning fork into close proximity to her antennæ, but she was not disturbed in the least. He then approached the feather of a pen very quietly, so as almost to touch first one and then the other of the antennæ, which, however, did not move. He then dipped the pen in the essence of *musk* and did the same; the antenna was slowly *retracted and drawn quite back.* He then repeated the same with the other antenna, and with like result. Care was taken throughout not to touch the antennæ. Lubbock then repeated the experiment with a number of *different ants*, and using *various substances.* The result in all cases was the same, and the inference was naturally drawn that the antennæ possessed the sense of smell. In these experiments various substances were taken, having nothing in common save the odour of musk that had been placed on them."[1]

(7) Its Uses or Merits.

(*i*) The Joint Method is chiefly used to *confirm* and strengthen the conclusions reached by the *Method of Agreement.* The negative instances confirm the conclusion based on the positive instances.

(*ii*) This method is not frustrated by a possible *Plurality of Causes.* It is employed especially to remedy the defect of the Method of Agreement arising from Plurality of Causes. The negative instances preclude the

1 Hibben: *Logic, Deductive and Inductive*, p. 250.

possibility of Plurality of Causes. This is the only method by which we can prove that a phenomenon is the *only* cause of another phenomenon provided the *negative* instances are *complete*. Carveth Read says: "It has one peculiar advantage, namely, that if the second list of instances (in which the phenomenon and its supposed antecedent are both absent) can be made exhaustive, it precludes any hypothesis of a plurality of causes; since all possible antecedents will have been included in this list without producing the phenomenon."[1]

(*iii*) This method is used in cases where the stricter Method of Difference cannot be applied. Where experiments are possible, we apply the Method of Difference. Where experiments are not possible, we apply the Method of Agreement and the Joint Method. The Joint Method confirms the conclusion of the Method of Agreement with the help of the negative instances. Thus, the Joint Method is mainly a *method of observation*. Therefore, it is the only useful instrument of proof in sciences which depend on observation.

"The Joint Method of Agreement and Difference has advantages over each of these methods separately. (1) It supplements the positive instances of Agreement by negative instances. (2) It applies in many cases where the conditions of the Method of Difference cannot be realised, *e. g.*, where experiment is impossible because we cannot control the conditions or produce the event at all."[2]

---

1 *Logic*, p. 213. 2 *The Elements of Logic*, p. 333.

(8) Its Defects.

(*i*) The Joint Method is chiefly a method of observation. So in this method it is very difficult to obtain a *large number* of instances and thereby *eliminate* all irrelevant circumstances.

(*ii*) The Joint Method fails to distinguish between *causation* from *co-existence*, and *cause and effect* from the *co-effects* of the same cause, like the Method of Agreement.

(*iii*) The Joint Method, though an extension of the Method of Agreement by the addition of negative instances, cannot conclusively prove the causal connection, because it is confined to observation and cannot eliminate hidden and unobserved factors. In fact, the conclusion of the Joint Method is often verified by the Method of Difference.

7. The Joint Method and the Method of Agreement.

The Joint Method agrees with the Method of Agreement in that it also depends upon *observation*, and its conclusions are *probable*. But the Joint Method differs from the Method of Agreement in that its conclusions are more probable owing to the addition of *negative* instances. The Joint Method is a double application of the Method of Agreement first to a set of positive instances and then to a set of negative instances. Both the methods cannot distinguish *causation* from *co-existence*, and *cause and effect* from the *co-effects* of the same cause. Both cannot *eliminate* all irrelevant circumstances.

8. The Method of Difference or the Method of Single Difference.

(1) It Object.

The object of this Method is to find out what particular antecedent cannot be introduced into or eliminated from, a particular group of circumstances without a particular consequent being introduced or eliminated.

(2) Its Canon.

"*If an instance in which a phenomenon occurs, and an instance in which it does not occur, have every other circumstance in common save one. that one (whether consequent or antecedent) occurring only in the former; the circumstance in which alone the two instances differ is the effect, or the cause, or an indispensable condition of the phenomenon.*" (*Carveth Read*).

"When the addition of an agent is follwed by the appearance, or its subtraction by the disappearance of a certain event, other circumstances remaining the same, that agent is causally connected with the event. (*Mellone*).

(3) Its requirements.

The Canon of Difference implies two conditions. In the first place, we require *only* two instances, one positive and the other negative. In the second place, they must be of a definite nature: they must *agree in all respects* except an antecedent and a consequent, which are present in the one case but absent in the other. We must be quite sure that when an antecedent is left out or intro-

1 Quoted in *Ibid*, p. 353.

duced, no other antecedent should disappear or appear without our knowledge. These requirements can be satisfied only where experiments are possible. **Therefore, the Method of Difference is pre-eminently a method of experiment.** Though it is very often applied to cases of observation, it is precarious to do so. It is chiefly the method of experiment as Agreement is the method of observation.

(4) Cautions to be observed.

(*i*) First, The Method of Difference requires that all other circumstances remaining the same, ***only one circumstance is introduced or withdrawn.*** If this condition is not satisfied, the Method cannot yield a certain conclusion. But it is extremely difficult to secure this condition in observation. It is possible only in experiment. (*ii*) Secondly, we should not confound the *liberating condition* for the *real cause.* We should not regard the pressing of the button as the real cause of lighting the house. The real cause is the electric force ; it is liberated by the action. (*iii*) Thirdly, we should see that the interval of time between the introduction of an agent and the appearance of a consequent is as short as possible.

(5) The Basic Principle.

Whatever antecedent cannot be left out without prejudice to the effect, must be its cause. Or whatever antecedent cannot be introduced without a consequent appearing, must be a cause or a part of its cause. "If when an element is added something appears, or when taken away it disappears, everything else remaining the same, this element is the cause." (*Cunningham*).

(6) Symbolical Examples.

(*i*) *A* B C followed by *p* q r
B C " " q r
∴ *A* is the cause of *p*.

(*ii*) B C followed by q r
A B C " " *p* q r
∴ *A* is the cause of *p*.

(7) Concrete Examples.

(1) The Method of Difference is very often employed in common experience. A man drinks water and his thirst is immediately quenched. So the drinking of water is the cause of the quenching of thirst. You load your gun and pull the trigger and the gun goes off. So pulling the trigger is the cause of the firing of a shot. The sun is suddenly covered by cloud and we feel cold. Hence, the sun is the cause of heat, or the cloud is the cause of cold. We should remember that it is very precarious to apply this method to cases of observation.

(2) Plunge a blue litmus paper in acid, it is changed into red. The change of colour is due to the action of the acid. The simple experiment conclusively proves it.

(3) Ring a bell in a jar filled with air. We hear the sound of the bell. Then pump out all the air from the jar and ring a bell in it. We do not hear any sound. Hence the experiment proves that the air is the cause of sound.

(4) "When a current of electricity is passed through a galvanometer the resulting deflection of the needle is ascribed to the current; when sodium is added to dilute

sulphuric acid it is regarded as causing the release of hydrogen; when a lesion is made in the cerebrum of frog there is no hesitation in connecting it with any consequent paralysis of movement."[1]

(5) A coin and a feather are dropped simultaneously in the receiver of an air pump filled with air. The feather reaches the bottom after the coin. Then air is pumped out of the receiver, and the coin and the feather are dropped simultaneously. They reach the bottom at the same instant. Therefore, the resistance of the air is the cause of the feather falling more slowly than the coin.

(6) Weigh a vessel filled with ordinary air. Then fill it with condensed air and weigh it again. The latter is found to be more heavy than the former. Therefore, the increased weight can only be due to greater quantity of air contained. Galileo made this experiment to show that air has weight.

(7) Insert the poles of a galvanic battery in a vessel of water. Bubbles rise from each pole and the water is gradually decreased. The bubbles are caught in receivers placed over them. The gases may be found to be oxygen and hydrogen by further experiments. This experiment proves that an electric current resolves water into oxygen and hydrogen.

(8) Tyndall found that of twenty-seven sterilized flasks containing infusion of organic matter, and opened in pure Alpine air, not one showed putrefaction: while

1 *An Introductory Logic*, p. 360.

of twenty-seven similar flasks, opened in a hay loft, only two remained free from putrefaction after three days. He concluded that putrefaction is due to floating particles or germs in the air.

(9) Pasteur made a similar experiment. He placed one quantity of fermentable substance in a closed air-tight vessel, and another equal quantity he exposed to the air. Otherwise the conditions were identical. He noted that in the case of the exposed substance fermentation took place, and that in the case of the substance protected from the air there was no fermentation. Thus having shown that the germs had been imported through the air he concluded that life does not originate spontaneously.

(10) Darwin showed that earthworms, though sensitive to mechanical tremors, are insensitive to sounds. "He placed a pot containing a worm that had come to the surface, as usual at night, upon a table, whilst close by a piano was violently played ; but the worm took no notice of the noise. He then placed the pot upon the piano, whilst it was being played, when the worm, probably feeling mechanical vibrations, hastily slid back into its burrow."[1] *(Carveth Read).*

(8) Its Merits.

(*i*) The requirements of this method are very stringent. They cannot be satisfied unless we take resort to experiment. Hence this method is called a *Method of Experiment.* Though it is used in common practice in

---

1 *Logic*, p. 221.

cases of observation too, it is rather precarious in the field of observation because we cannot make sure that other circumstances remain the same.

(*ii*) But when it is applied experimentally, it supplies what Bacon calls an *experimentum crucis* or test to confirm the conclusion already drawn with less certainty by the Method of Agreement. It thus possesses superior certainty when applied by experiment.

(*iii*) This Method is the simplest of all the methods. It does not require several instances. Only *two* instances are sufficient for its purpose, one positive and the other negative, all other circumstances remaining the same.

(*iv*) *It is not liable to be frustrated by a possible Plurality of Causes.* The particular effect may be produced by different causes at different times ; but there is no doubt that in this instance the *particular antecedent is the cause of the particular consequent.* A man takes opium and dies. Though death may be due to different causes at different times, there is no doubt that in this instance it is caused by opium. By the Method of Difference, therefore all that we can prove is that a phenomenon is *a* cause of another phenomenon, not *the* cause.

(9) Its Defects.

(*i*) The Method of Difference being chiefly a *method of experiment*, it suffers from the defects of experiment. For example, *this method cannot be directly applied in reasoning from effects to causes.* It can be applied in reasoning from effects to causes only by the round-about method of first using hypotheses.

"The method directly investigates the effects of a given cause. It works forwards, from cause to effect. Regarded as a mode of discovering the cause of a given effect, it is an application of the indirect method. We assume the possibility of a given cause as sufficient to account for the phenomenon in question. We then try to introduce that cause into a suitable set of conditions so as to see if it fulfils our expectation by securing the change which we believe it capable of producing."[1]

(*ii*) The Method of Difference is seldom applicable to phenomena which are beyond the range of experiment. Therefore, in sciences mainly based on observation, (*e. g.*, History, Politics, Economics, *etc.*) this method cannot always be applied with advantage.

(*iii*) It is extremely difficult to make sure that no other influential circumstance shall be added to, or subtracted from, the given group of circumstances except the particular circumstance we are considering. Another antecedent and a consequent may slip in or slip out without our knowledge, and frustate the method. "To obviate this and make the experiment decisive there should be *one* circumstance added to or withdrawn from known conditions." (*Welton*).

(*iv*) The Method of Difference cannot prove that a phenomenon is the *only* cause of another phenomenon. It is only the Joint Method that can prove it provided the negative instances are exhaustive. It can prove that a phenomenon is a cause of another phenomenon.

1 *An Intermediate Logic*, p. 360.

9. Comparison of the Method of Agreement with the Method of Difference.

(1) Both involve comparison of instances. The Method of Agreement shows their points of *agreement*, while the Method of Difference shows their points of *difference*. In the former the instances *agree* in *one* point only, while in the latter they *differ* in *one* point only. So the former is called the Method of Single Agreement, and the latter, the Method of Single Difference.

(2) The Method of Difference is much simpler than the Method of Agreement. The former requires only *two* instances, while the latter requires a *large number* of instances.

(3) The Method of Agreement is based on the principle that whatever *can* be eliminated has *no* causal connection with the phenomenon. But the principle of the Method of Difference is that whatever *cannot* be eliminated *has* causal connection with the phenomenon.

(4) The Method of Agreement is chiefly a method of *observation*, and that of Difference chiefly a Method of *experiment*.

(5) Therefore, the Method of Agreement enables us to reason *from causes to effects* as well as from *effects to causes*, while the Method of Difference is *directly* applicable in reasoning *only from causes to effects*.

(6) The Method of Agreement is both the method of *discovery and proof*, while the Method of Difference is only the method of *proof*. Generally the Method of Agreement suggests a *hypothesis* which is verified by the Method of Difference.

(7) The Method of Agreement does not enable us to overcome the difficulty arising from the Plurality of Causes, whereas the Method of Difference enables us to overcome this difficulty. The Method of Agreement is frustrated by the Plurality of Causes, while the Method of Difference is not, but all that the Method of Difference can prove is that a phenomenon is *a* cause of another phenomenon but not *the only* cause.

(8) The Method of Agreement yields *probable* conclusions, while the Method of Difference yields *certain* conclusions.

10. Is the Joint Method a modification of the Method of Agreement or the Methods of Agreement and Difference both?

The Joint Method is regarded by some as combining the principles of the Methods of Agreement and Difference. Hence it is called by them the Joint Method of Agreement and Difference or simply the Joint Method. Others again take it to be simply an extension of the Method of Agreement to negative instances. Hence, it is called the Double Method of Agreement or the Method of Double Agreement, or the Joint Method of Agreement in presence and Agreement in absence.

The first view does not seem to be tenable. The Joint Method does not include the Method of Difference and seldom commands the certainty of this method. It does not fulfil the conditions of the Method of Difference. It should rather be regarded as a modification of the Method of Agreement. It is an extension of, and improve-

ment upon it. It suffers from some of the defects of the Method of Agreement but is not liable to be defeated by Plurality of Causes.

11. The Joint Method and the Method of Difference.

The Joint Method seems to combine the principles of the Method of Agreement and the Method of Difference. Hence it is sometimes called the Joint Method of Agreement and Difference and sometimes the Indirect Method of Difference. The positive instances illustrate the principle of the Method of Agreement, and the negative instances illustrate the principle of the Method of Difference.

But this can hardly be maintained. If we take the positive instances *as a whole* and if we take the negative instances *as a whole*, we may call the Joint Method the Indirect Method of Difference. But the essential condition of proof in the Method of Difference is that the negative instance must differ from the positive one in respect of *one* circumstance only. The irrelevant circumstances must be absolutely the same in both the instances. This condition cannot be fulfilled in the Joint Method. Being mainly a method of observation it can seldom eliminate all the inessential circumstances. Moreover, it cannot distinguish cause and effect from the co-effects of the same cause. Hence none of the conditions which give so much value to the Method of Difference are fulfilled by the Joint Method. Both the methods are free from defects arising from Plurality of Causes. The Joint Method is chiefly a method of observation. The

Method of Difference is chiefly a method of experiment. So the former yields a probable conclusion, while the latter yields a certain conclusion.

12. The Method of Concomitant Variations.

(1) Its Object.

The object of this Method is to vary the antecedent and the consequent in cases in which it is not possible to isolate or eliminate them completely.

(2) Its Canon.

"*Whatever phenomenon varies in any manner, whenever another phenomenon (consequent or antecedent) varies in some particular manner is either the cause or effect of that phenomenon or is connected with it through some fact of causation.*" *(Carveth Read).*

"Concomitant variations" mean variations of two phenomena together or side by side. They are not necessarily variations in the same direction. Two phenomena may be said to vary together or *concomitantly* even when they vary inversely. If two phenomena increase together or decrease together, they are said to vary concomitantly. If one phenomenon increases or decreases and another phenomenon decreases or increases respectively, they also are said to vary concomitantly. In the first case, they vary *directly*. In the second, they vary *inversely*.

(3) Its Basic Principle.

When an antecedent and a consequent vary in numerical concomitance either *directly or inversely*, we conclude that they are causally connected.

(4) Symbolical Examples.

(1) Direct Variation :—

(i) *A* B C	followed	by	*p* q r
2 *A* B C	,,	,,	2 *p* q r
3 *A* B C	,,	,,	3 *p* q r

∴ *A* is the cause of *p*.

This is an example of the Method of Concomitant Variations as a modification of the *Method of Difference*. Here *B C* and *q r* are common to all the instances.

(ii) *A* B C	followed	by	*p* q r
2 *A* C D	,,	,,	2 *p* r s
3 *A* D E	,,	,,	3 *p* s t

∴ *A* is the cause of *p*.

This is an example of the Method of Concomitant Variations as a modification of the *Method of Agreement*. Here *A* and *p* are common to all the instances, and all other circumstances are variable.

(2) Inverse Variation:—

(i) *A* B C	followed	by	*p* q r
2 *A* B C	,,	,,	$\frac{1}{2}$ *p* q r
3 *A* B C	,,	,,	$\frac{1}{3}$ *p* q r

∴ *A* is the cause of *p*.

This also is an example of the Method of Concomitant Variations as a modification of the *Method of Difference*. Here *B C* and *q r* are common to all the instances.

(ii) *A* B C followed by *p* q r
2 *A* C D followed by $\frac{1}{2}p$ r s
3 *A* D E followed by $\frac{1}{3}p$ s t
∴ *A* is the cause of *p*.

This is an example of the Method of Concomitant Variations as a modification of the *Method of Agreement*. Here *A* and *p* are common to all the instances. All other circumstances are variable.

J. S. Mill regarded the Method of Concomitant Variations as a modification of the Method of Difference. **Carveth Read** holds that it may also be regarded as a modification of the Method of Agreement. When the accompanying circumstances are the *same*, it is a modification of the Method of Difference. When the accompanying circumstances are *different*, it is a modification of the Method of Agreement. In the former case, the conclusion is *certain*. In the latter, the conclusion is *probable*. In the former, the method is not frustrated by the possible Plurality of Causes. In the latter, the method is frustrated by it.

(5) Concrete Examples.

(1) As scarcity of food increases, agrarian crimes increase. As scarcity of food decreases, agrarian crimes decrease. Therefore scarcity of food is a cause of agrarian crimes. Here there is direct variation.

(2) As education increases, superstition decreases. As education decreases, superstition increases. Therefore education destroys superstition. Here there is inverse variation.

(3) The greater is the height of a place, the less warm is its climate. The less is the height, the more warm is the climate. So height is the cause of low temperature. Here there is inverse variation.

(4) Pascal observed that as he ascended higher and higher up a hill, the weight of the atmosphere became less and less. As the weight of the atmosphere became less and less, the height of the column of mercury in a *barometer* became less and less. Therefore he concluded that the weight of the atmosphere is the cause of the height of the mercury in a barometer. Here there is direct variation.

(5) It is a matter of common experience that as the temperature of the medium (*e. g.*, atmosphere, water, or human body) increases, the height of the column of mercury in a *thermometer* applied to it increases, and as the temperature decreases, the height of the mercury decreases. Therefore heat is the cause of expansion. The heat of the medium expands the mercury in the hollow tube of the thermometer. Here there is direct variation.

(6) "Instead of striking a bell in a complete vacuum, we can strike it with a very little air in the receiver of an air-pump, and we then hear a very faint sound, which increases or decreases every time we increase or decrease the density of the air. This experiment conclusively satisfies any person that air is the cause of the transmission of sound."[1] *(Jevons)*.

(7) The greater the friction between two material bodies, the greater the heat produced. The heat is exactly greater or less in proportion as the force

1 *Elementary Lessons in Logic*, p. 250.

employed in friction is greater or less. So friction is the cause of heat.

(8) The more we attend to an object (*e. g.*, a poem), and the more frequently we repeat it, the more we can retain it in memory. So attention and frequency are conditions of memory.

(9) The weight of a body varies directly as its mass and inversely as the square of its distance from the centre of the earth. In other words, (1) as the mass of a body increases, its weight also increases, and (2) as the distance of a body from the centre of the earth increases, its weight decreases. So the mass and the distance from the centre of the earth determine the weight of a body.

(10) The greater is the weight of the brain, the greater is the intelligence. We cannot remove the brain of a living man. We can weigh the brains of deceased persons whose mental powers are known to us. We find that the heavier is the brain, the greater is the intelligence, and the lighter is the brain, the less is the intelligence. "The average brain of civilized men weighs about 49 oz.—that of savage races about 4 to 6 oz. less. Men of genius have risen as high as 64. Idiots may not rise above 30, and may sink as low as 10."[1] Sometimes comparatively small brains carry greater intelligence because of their greater complexity and organisation. Therefore brain development and mental development are causally connected with each other.

1 Henry Stephen: *Analytical Psychology*, 1913, p. 57.

(6) Its Uses or Merits.

(*i*) The chief use of this method is that it is especially applicable to the investigation of those phenomena which *cannot be completely eliminated*, and, consequently, cannot be investigated by the Method of Difference. **It is applicable to the investigation of "Permanent Causes."** There are certain phenomena, such as gravitation, heat, friction, atmospheric pressure, etc., which can never be eliminated altogether, and therefore can be investigated only in their varying degrees. The Method of Difference cannot be applied to such phenomena, because we cannot get their negative instances. But we can *vary* them and observe the effects of their variation, though we can never get instances of their *absence*. For example, we cannot completely eliminate atmospheric pressure, but we can put ourselves in positions where we can observe its variations. As we ascend a mountain higher and higher, we find the atmospheric pressure less and less. These agencies which cannot be completely eliminated are called by Mill "permanent causes." They can be investigated only by the Method of Concomitant Variations. It is applied to those cases where it is impossible to apply the Method of Difference.

(*ii*) It is a **quantitative method** as distinguished from the qualitative Methods of Agreement, Difference, and Joint Method, which prove that a phenomenon is a cause of another phenomenon, but cannot prove *how much* of the former is a cause of *how much* of the latter. But the Method of Concomitant Variations can determine the

quantitative relation between cause and effect. "In cases where the variations are exactly measurable, the Method of Concomitant Variations gives very much more precise results than the other methods. In such cases it can not only support the other methods but it gives something which they cannot give. It then becomes a method not only of establishing causal relations between phenomena but also of determining the precise *quantitative relations* between them."[1] By this method we can find out *how much* of a cause produces *how much* of an effect.. It seeks to reduce the causal relation to a quantitative formula. It seeks to establish *quantitative equivalence* between cause and effect, (*e. g.*, heat and motion). The amount of energy in heat is identical with the amount of energy in the resulting motion, so that the relation between them is quantitative equality.

(*iii*) The Method of Concomitant Variations is of the greatest value when the variations in degree can be exactly measured. In this respect it has the advantage over the qualitative methods we have already considered. A causal relation which has been suggested by the Method of Agreement, and established by the Joint Method or the Method of Difference, is rendered *precise* when it is determined as a relation of *quantity* by the Method of Concomitant Variations.

(*iv*) This method is frustrated by *Plurality of Causes*, when it is a modification of the *Method of Agreement*. When the accompanying circumstances are different, we cannot make sure if the variations of the phenomena are not due to the different accompanying circumstances. But

1 *The Elements of Logic*, p. 339.

this method is free from the difficulty arising from Plurality of Causes, when it is a modification of the Method of Difference—all the accompanying circumstances remaining the same.

(7) Its defects or limitations.

(*i*) *The Method of Concomitant Variations cannot be applied beyond certain limits.* It is applicable only within the range of experience. This method shows that two phenomena are causally connected because they vary together. But they do not vary concomitantly beyond certain limits. For example, water expands when heated, and contracts when cooled. As heat increases, water expands in volume. But when its temperature rises above 212° F., it undergoes a sudden expansion, and it turns into a gas. When water cools, it contracts between 212° F. and 39° F. But when its temperature falls below 39° F., it begins to expand, until at 32° F., it becomes solid and expands considerably. This example shows that concomitant variations are very regular in the 'median range,' and are apt to become irregular at the upper limit and the lower limit, where new conditions begin to operate.[1] The Method of Concomitant Variations is not applicable at these "critical points."

Weber's Law is based on the Method of Concomitant Variations. Roughly it states that as the intensity of the stimulus increases, the intensity of the sensation increases. It states that a definite fraction of the stimulus must be added to it, before we can discern

1 *The Elements of Logic*, p. 339.

a difference in sensation. The stimulus and the sensation vary concomitantly. But this concomitant variation is not uniformly continuous. It holds good in the 'median range'. It tends to become irregular at the upper limit and the lower limit of the range of sensibility. The sensation increases more rapidly towards the lower limit, and less rapidly towards the upper limit. Again, we cannot feel any sensation above the highest limit, though the intensity of the stimulus is further increased. Nor can we feel any sensation below the lowest limit, though the intensity of the stimulus is further decreased. A very bright light dazzles our eyes. A very faint light fails to produce a sensation in us. Thus, the concomitant variation of the stimulus and the sensation has an upper and lower limit, beyond which it either changes its character or ceases altogether. The Method of Concomitant Variations, therefore, has obvious limits.

(*ii*) The Method of Concomitant Variations cannot be applied to *qualitative* variations. It is applicable to quantitative variations only. It is a *quantitative method* as distinguished from the qualitative methods of Agreement, Difference, and Joint Method. It is a useful supplement to the qualitative methods.

(*iii*) This method cannot distinguish *causation* from *co-existence*, and *cause and effect*, from the *co-effects* of the same cause. All that it can establish is that two phenomena varying concomitantly are causally connected. It cannot precisely determine the nature of the causal

---

1 Carveth Read : *Logic*, p. 230.

connection. When variations cannot be exactly measured, it cannot conclusively prove a causal relation.

13. The Method of Concomitant Variations and the Method of Difference.

The Method of Concomitant Variations is only a peculiar application of the Method of Difference to phenomena which cannot be completely eliminated. There are some agencies in nature which are everywhere present and can never be entirely eliminated such as gravitation, friction, temperature, atmospheric pressure, etc. We cannot get negative instances of these phenomena, because they are never absent. They are called by Mill "**Permanent Causes.**" So the Method of Difference cannot be applied to them. Nevertheless these phenomena can be studied in different degrees because they are subject to variation. Therefore, they can be investigated by the Method of Concomitant Variations.

The Method of Concomitant Variations is a modification of the Method of Difference. Let us illustrate it by an example. If the amount of heat is increased from 60° to 70° and if another phenomenon (*e. g.*, expansion) varies in a corresponding manner, we are really applying the Method of Difference to find out the effect of the additional 10°. The temperature of 60° may be regarded as a negative instance in which the phenomenon of the extra 10° does not occur, and the temperature of 70°, as a positive instance in which the phenomenon of the extra 10° occurs. Thus, we have conditions which correspond to those of the Method

of Difference. The Method of Concomitant Variations is a modification of the Method of Difference suited to the investigation of the cause and the effect which are not wholly eliminated but vary together.

14. The Method of Residues.

(1) Its object.

The object of this method is to account for the residue of a complex phenomenon, the other parts of which have already been explained by known causes. It calls attention to the "unexplained remainder" of a complex phenomenon, and seeks to explain it by a hitherto unknown agent.

(2) Its Canon.

"*Subduct from any phenomenon such part as previous inductions have shown to be the effect of certain antecedents, and the residue of the phenomenon is the effect of the remaining antecedents.*" (*Carveth Read*).

(3) Its Basic Principle.

This method is based upon the quantitative equivalence of the cause and the effect. It is based on the assumption that a cause must be adequate or *equal* to the effect. When a part of a complex effect has been accounted for by known causes, the residual phenomenon leads us to the discovery of an unknown similar cause.

(4) Symbolical Example.

A B C	followed	by	*p* q r
B C	"	"	q r

∴ *A* is the cause of *p*.

(5) Element of Deduction in the Method of Residues.

Here there are two instances,—one positive and the other negative. The positive instance is known by observation or experiment. The negative instance is derived from *deduction from previous inductions*. We know by *previous inductions* that B is the cause of q, and C is the cause of r. And then we *deduce* the joint effect q r from the causes B C acting jointly. And then we subtract the negative instance from the positive instance and conclude that the remaining antecedent *A* is the cause of the remaining consequent *p*.

(6) Concrete Examples.

(1) We weigh a tin filled with *ghee*. Then we subtract the weight of the tin known already from the total weight. Thus we find out the weight of *ghee*.

(2) There are many phenomena in the living body which cannot be accounted for by known physical and chemical forces. For example, growth, self-recuperation, self-reproduction, assimilation, circulation and inhalation cannot be explained by these forces. So we conclude that they are due to vital force.

(3) If A, B and C can do a piece of work in 10 days; A alone can do it in 20 days, and B alone can do it in 30 days, we can find out how many days C will take to do it.

(4) "We can find out how much of the spring tide is due to the attraction of the sun. By previous inductions we know the average height of the tide due to the moon. Subtracting this from the whole height, we get the remain-

ing part of the spring tide due to the attraction of the sun."[1]

(5) Many of the the new elements of chemistry have been discovered by applying the Method of Residues. The investigations of *residual phenomena* have led to their discovery. When electricity is passed through the air, it is accompanied by a peculiar odour known as "electrical smell." This unexplained phenomenon led to the discovery of **Ozone.**

(6) Nitrogen in the atmosphere was found to be slightly heavier than nitrogen obtained from chemical sources. Atmospheric nitrogen was found to be ½ per cent. heavier than pure nitrogen produced in the laboratory. Lord Rayleigh and Sir W. Ramsay proved that the increased weight was due to the presence of some other inert gas hitherto undetected. Thus they discovered **Argon** in 1894.

(7) Herschel says: "Almost all the greatest discoveries in Astronomy have resulted from the consideration of residual phenomena of a quantitative kind." The planet **Neptune** was discovered by Adams and Leverrier in 1846 by applying the Method of Residues. Certain deviations were found in the movements of Uranus. They could not be accounted for by the attraction of the sun and the known planets. Uranus deviated from the calculated path. "The sun and the known planets have a calculable effect in disturbing the path of Uranus in its elliptic orbit, but there were residual perturbations which could not be thus accounted for. From these the orbit and position of

1 **P. D. Shastri** : ***Inductive Logic***, **pp. 135-36.**

Neptune were calculated."[1] (*Mellone*). And it was actually discovered in the calculated position with a powerful telescope.

(8) The above examples of the Method of Residues are all *quantitative*. But the method is also employed where exact measurements cannot be obtained. Darwin explained the evolution of species of animals by the Law of Natural Selection. But he found certain modifications of animals in form, coloration and habits, which could not be explained by Natural Selection. So he accounted for these residual phenomena by Sexual Selection.[2]

(7) Forms of the Method of Residues.

In the first place, the method is applied to a complex phenomenon which is the result of several causes to find out what part *each* of the causes plays in the production of the complex effect. "This may be illustrated by an example: after my student's lamp has been lighted two hours I find the thermometer has risen from 65° to 70° F. The phenomenon to be explained then is the additional 5° of heat. There is no fire, and it seems that the increase in temperature must be due to the lamp, and the heat given off from my body during this period. Suppose that the lamp is burned for the same length of time while the room is unoccupied, all other conditions remaining the same, and that the thermometer shows an increase of 4° in the temperature. By subtraction we could conclude that the

1 *An Introductory Text-Book of Logic*, 7th edition, p. 316.

2 Carveth Read : *Logic*, p. 235.

heat given off by the body on the former occasion was the cause of the additional degree of temperature."[1]

In the second place, the method is applied to account for an "unexplained remainder" of a complex effect by an unknown *Cause*, after the joint effect of all the known causes has been calculated. We have seen how the attempt to account for unexplained residue has led to many discoveries. Neptune was discovered to account for the deviation of Uranus from the calculated path due to the attraction of the sun and the known planets. Argon was discovered to account for the additional weight of atmospheric nitrogen. Ozone was discovered to account for the "electrical smell." A residual phenomenon leads to the discovery of its cause. Melione lays down the following canon to cover such cases:—

"*When any part of a complex phenomenon is still unexplained by the causes which have been assigned, a further cause for this remainder must be sought.*"[2]

Thus the Method of Residues is a method of discovery *rather than of proof.* It suggests hypotheses.

(*iii*) In the third place, the method may be applied to a complex phenomenon brought about by a conjunction of causes, to find out the *effect* of a residual cause after the effects of other causes have been determined. A B C jointly produce *x*. We have already determined what part of *x* has been produced by A and B. Then we may find out what part of *x* is produced by the residual antecedent C by the Method of Residues. "The unforeseen effects of

1 *An Introductory Logic*, 1932, p. 301.
2 *An Introductory Text-Book of Logic*, p. 315.

changes in legislation, or of improvements in useful arts, may often be discerned by the Method of Residues."

(8) Its Uses.

(*i*) The Method of Residues is particularly useful for the analysis of *complex* phenomena. We may leave out the causes and effects we already know, and thus simplify the phenomena to a great extent. As scientific knowledge advances, residuary phenomena increase in number and importance, which may be explained by this method.

(*ii*) It is a method of *discovery* rather than of proof. It is one of the most important sources of scientific discovery. It has been used with great success in Astronomy and Chemistry. Of all the methods of investigating nature, it is the most fertile in unexpected results.

(*iii*) It presupposes some knowledge of causes and effects. It depends on previous inductions. We cannot employ this method where nothing is known beforehand. It presupposes same progress in our investigations of causes and effects.

(*iv*) It can be applied to cases of observation as well as experiment. In cases of experiment it is a *quantitative* method. In cases of observation it is a *qualitative* method.

(*v*) It is the only method which is not frustrated by the *Intermixture of Effects*. It is usually applied to homogeneous intermixture of effects. It cannot adequately cope with heteropathic intermixture of effects.

15. The Method of Residues and the Method of Difference.

The Method of Residues is a modification of the Method of Difference. Both require two instances,—one *positive* and the other *negative*,—which differ only in one circumstance (antecedent or consequent), which is present in the former, and absent in the latter. Both are based on the same principle. The circumstance in which alone the instances differ is the cause or the effect of the phenomenon under investigation. But there is an important distinction between the Method of Residues and the Method of Difference. The distinction lies in the manner in which the *negative instance* is obtained. In the Method of Difference, it is obtained by observation and experiment, while in the Method of Residues, it is obtained by *deduction from previous inductions.* The Method of Difference does not directly contain any element of deduction, while deduction plays an important part in the Method of Residues. The Method of Difference does not presuppose any knowledge of causes and effects. But the Method of Residues cannot be employed without any previous knowledge of causes and effects by inductions. The former is a *qualitative* method, while the latter is usually a *quantitative* method.

16. Is the Method of Residues deductive ?

The negative instance is obtained by *deduction* from previous inductions in the Method of Residues. We observe that certain antecedents are followed by certain consequents. Then we deduce or calculate the effects of known causes. Then we subtract this calculated effect

from the total effect. Then we infer that the residual antecedent is the cause of the residual consequent. Thus deduction plays an important part in this method. The prominence of deduction in this method has led some logicians to treat it as a deductive method rather than an inductive method.

But this view is wrong. First, though deductive calculation plays an important part in supplying the negative instance, observation and experiment initiate the inductive investigation by supplying the positive instance. Secondly, "the method is generally applied to the result of previous inductions and generally suggests subsequent inductions."[1] (*Fowler*). It is by inductions that we know that B is the cause of *q* and *C* is the cause of *r*. By the Method of Residues we determine that the remaining antecedent A is the cause of the remaining consequent *p*. This is also an induction. Thirdly, all the canons of the Inductive Methods are *deductions* from the Law of Causation, but they are not called deductive methods for this reason. Fourthly, the framing of a hypothesis and *deduction* of its consequences are essential to all the Inductive Methods as a preliminary step. But it does not make them deductive methods. Therefore, the Method of Residues should be regarded as an *inductive* method.

17. The Special Feature of the Method of Residues.

This method cannot be employed unless we have acquired some knowledge of causes and effects. It presupposes some progress of scientific knowledge. When

1 *Inductive Logic*, 6th edition, p. 174.

a major part of a complex phenomenon has been accounted for by known causes, we try to account for its "unexplained remainder" by employing the Method of Residues. This is the special feature of this method. It has led to many important discoveries. It effectively deals with the homogeneous intermixture of effects.

18. The Relation of the Method of Residues to the other Inductive Methods.

The object of the Inductive Methods is to help us in ascertaining the Laws of Nature. We observe particular phenomena of nature and discover their laws with the help of the Inductive Methods. But we never observe the phenomena of nature and investigate their causes in a state of absolute ignorance. Nor do we take the trouble of investigating over again the laws which we already know by previous inductions. Therefore, our investigations are confined to the *residue*, the cause of which we do not know. In this sense, all the Inductive Methods may be said to involve the use of the Method of Residues. Thus the special problem of induction begins where the Method of Residues leaves off.

19. The Methods of Observation and Experiment.

The Method of Agreement and the Joint Method are pre-eminently methods of observation. The kind of instances required by them can be supplied by observation; where experiments are possible, we do not employ these methods because they do not yield certain conclusions. We employ the Method of Agreement, when

we can obtain only positive instances of the phenomenon under investigation. We employ the Joint Method, when we can gather both positive and negative instances of the phenomenon. In both the methods the instances are supplied by observation. But we should not think that these methods cannot be applied to cases of experiment.

The Method of Difference is pre-eminently a method of experiment. The requirements of this method are very strict. It requires only two instances, one positive and the other negative, and they must agree in *all* circumstances except in one. This condition can be fulfilled only by experiment. For the same reason, the **Method of Residues** also, which is a modification of the Method of Difference, is mainly a **method of experiment.** If it is based on exact quantitative measurement, it is a method of experiment. But we should not think that these methods are not applicable to cases of observation. When they are applied in the field of observation, they yield precarious conclusions.

The Method of Concomitant Variations may be both a method of observation and experiment. When it is a modification of the Method of Agreement, it is a method of observation. When it is a modification of the Method of Difference, it is a method of experiment.

20. The Quantitative Methods.

The Method of Concomitant Variations and the Method of Residues are based on *quantitative* measurements of antecedents and consequents. Hence they are called *quantitative methods*. The Methods of Agreement,

Difference, and Joint Method are called the *qualitative* methods. They can establish the causal connection between two phenomena. But they cannot reduce it to a quantitative formula. The quantitative methods, on the other hand, not only establish a causal connection between them but determine their quantitative relation. The qualitative methods can prove that a phenomenon is a cause of another phenomenon. The quantitative methods can prove how much of the cause produces how much of the effect.

21. The Methods of Discovery and Proof.

The Method of Agreement *suggests* causal connection, but cannot prove it. It is an observational method and suggests a hypothesis. This hypothesis is proved by the Joint Method and the Method of Difference. The difficulty arising from the Plurality of Causes in the Method of Agreement is removed by the Joint Method by observing a set of negative instances. A hypothesis suggested by the Method of Agreement is conclusively proved by the Method of Difference which is essentially a method of experiment. Thus both the Joint Method and the Method of Difference are Methods of Proof. The Joint Method may be a Method of Discovery also, because it also suggets a hypothesis.

The Method of Concomitant Variations and the Method of Residues are fruitful sources of discovery. When two phenomena vary concomitantly, we at once suspect a causal connection between them. When the Method of Concomitant Variations is a modification of the Method of Difference, it is a Method of Proof.

The Method of Residues tries to find out the cause of a residual phenomenon. So it is a fruitful source of discovery. Neptune and Argon were discovered by the employment of this method. It is a special form of the Method of Difference. So it is also a Method of Proof.

22. The Unity of the Methods.

The different Experimental Methods are not equally fundamental. The Methods of Agreement and Difference are the two fundamental methods and the rest are only the modifications of these two. This is the view of **Mill.** The Joint Method is called by Mill the Indirect Method of Difference. But the Joint Method should be regarded as an extension of the Method of Agreement. It is the Double Method of Agreement in presence and Agreement in absence. The Method of Concomitant Variations has been regarded by Mill as a modification of the Method of Difference applied to those cases where the phenomena under investigation cannot be completely eliminated. But Carveth Read has pointed out that the Method of Concomitant Variations may also be regarded as a modification of the Method of Agreement where the irrelevant circumstances are not the same in all the instances. The Method of Residues is a modification of the Method of Difference in which the negative instance is not obtained by observation or experiment but by deduction from previous inductions.

Carveth Read tries to show that the Method of Difference is more fundamental than the Method of Agreement. "The cogency of the Method of Agreement

as distinguished from Simple Enumeration depends upon the omission, in one instance after another, of all other circumstances; which omission is a point of difference."[1] Others, again, hold that the Method of Agreement is more fundamental than the Method of Difference because mere difference can prove nothing.

It is more reasonable to hold with Mill that the Methods of Agreement and Difference are equally fundamental. Agreement implies Difference and Difference implies Agreement. Both are essential and fundamental.

23. Difficulties of the Experimental Methods.

The circumstances that tend to frustrate the Experimental Methods may be grouped under two heads, *viz.*, (1) difficulties in the acquisition of proper materials, and (2) difficulties that affect the validity of the Experimental Methods.

(1) The difficulties in the acquisition of proper materials are the difficulties of Observation and Experiment. By Observation it is often very difficult to obtain a sufficient number of instances under a sufficient variety of circumstances for the purpose of eliminating the irrelevant antecedents and isolating the relevant ones to find out the cause of a given phenomenon. The Method of Agreement and the Joint Method which are predominantly the methods of observation, labour under this difficuly. By Experiment, again, it is often very difficult to reproduce things and events in such a way as to meet the stringent requirements of the Experimental Methods like the Method of Difference.

1 *Logic*, p. 236.

(2) The difficulties that affect the validity of the Experimental Methods arise mainly, from three causes, *viz.*, (i) Plurality of Causes, (ii) Conjunction of Causes, and (iii) Intermixture of Effects.

(i) Plurality of Causes.

By "Plurality of Causes" we mean that the same effect (*e.g.*, death) may be due to different causes (*e. g.* cholera, small-pox, plague, burning, drowning, etc.,) *at different times.* We have already found that this doctrine cannot be maintained from the scientific point of view. But still it may be regarded as true from the practical point of view. We have also found that this doctrine affects the different experimental methods in a different manner. Here we shall simply sum up our observations.

The Method of Agreement is frustrated by the possibility of Plurality of Causes. But the difficulty arising from Plurality of Causes may be *partially* remedied by *multiplication of instances*; and it may be completely remedied by the *Joint Method.*

The Method of Difference is not frustrated by a possible Plurality of Causes. But all that it can prove is that a phenomenon is *a* cause (*i. e. one* of the causes) of another phenomenon, not *the* cause (*i. e.* the *only* cause).

The Joint Method is not at all affected by the possibility of Plurality of Causes. In this Method the negative instances contain all the antecedents that might be the possible causes of the phenomenon under investigation in the positive instances and still the phenomenon or the consequent does not appear. So the negative instances

remove the defect arising from Plurality of Causes. In fact, it is the only Method which can prove that a phenomenon is *the* cause (*i. e.* the *only* cause) of another phenomenon, if we can exhaust the list of negative instances.

The Method of Concomitant Variations is not affected by Plurality of Causes when it is a modification of the Method of Difference. But when it is a modification of the Method of Agreement, as shown by Carveth Read, it is liable to be frustrated by Plurality of Causes. When, *all* other circumstances remaining the same, two phenomena vary in numerical concomitance, they *must* be causally connected. Here, there is no possibility of Plurality of Causes. But when, besides these two phenomena varying in *numerical concomitance*, other circumstances also vary, the variation in the consequent may be due also to the variation of the other different antecedents in different instances. Thus, the Method of Concomitant Variations is not entirely free from the difficulty arising from Plurality of Causes.

The Method of Residues is not frustrated by Plurality of Causes as it is a modification of the Method of Difference.

(ii) Conjunction of Causes.

By "Conjunction of Causes" we mean that an effect is sometimes produced by many causes co-operating together. Mill calls it "Composition of Causes." The Experimental Methods proceed on the assumption that a *single* antecedent is the cause of a *single* consequent ; and they try to find out the causal antecedent

by eliminating the irrelevant antecedents. So. when several antecedents co-operate to bring about a single effect, the Experimental Methods fail to find out the *whole* cause.

The difficulties arising from Composition of Causes may be overcome in the following two ways:—

(*a*) By distinguishing between *remote* antecedents and *immediate* antecedents, and considering a cause as a *combination of antecedents immediately present in space and time.*

(*b*) By distinguishing between *concomitant* conditions and *determining* conditions, and regarding the latter as the cause of the phenomenon under investigation. Concomitant conditions are those antecedents which are necessary to the production of the effect, but which cannot bring about the effect unless some other antecedents are added to them. Determining conditions are those antecedents which *must* be added to the former in order to bring about the effect.

(iii) Intermixture of Effects.

By "Intermixture of Effects" we mean that the separate effects produced by different causes are blended together in such a way that it is difficult for us to trace different causes. The difficulty arising from Intermixture of Effects may be overcome by the application of the Method of Residues. It can effectively cope with homogeneous intermixture of effects. All other Experimental Methods except the Method of Residues are affected by the possibility of Intermixture of Effects. But the difficulties due to Composition of Causes and Intermixture

of Effects are most effectively overcome chiefly by the Deductive Method.

24. The Deductive Character of the Experimental Methods.

The Experimental Methods are based on certain principles which are deduced from the Law of Causation. We have already discussed the basic principles on which the different Experimental Methods are based. Thus, first we state the Law of Causation which is presupposed by Induction. Then, we draw certain immediate inferences from the Law of Causation in the form of certain causal principles. Then, we deduce certain Canons (*i. e.* the Inductive Canons) from these causal principles. And then, these Canons are applied to special instances, if they satisfy the requirements of the Canons, and thus find out causal connection. Thus, the application of the Experimental Methods is purely *formal* or *deductive* in character. "These are," says Bain, "called by courtesy Inductive Methods ; they are more properly Deductive Methods, available in Inductive investigations." Carveth Read also remarks that Inductive Logic may be considered as having a purely formal character. As Carveth Read says : "Iductive Logic may be considered as having a purely formal character. It consists (1) in a statement of the Law of Cause and Effect ; (2) in certain immediate inferences from this Law, expanded into the Canons ; (3) in the syllogistic application of the Canons to special predications of causation by means of minor premises, showing that certain instances satisfy the Canons."[1]

1 *Logic*, p. 236.

The deductive character of the Method of Agreement may be shown by reducing it to a syllogism thus:—

A B C	followed	by	*p q r*
A C D	...	...	*p r s*
A D E	...	...	*p s t*

$\therefore$ *A* is the cause of *p*.

It may be reduced to the following syllogism :—

Whatever antecedent can be eliminated without prejudice to the effect is not the cause ;

B, *C*, *D*, *E*, can be eliminated :

$\therefore$ *B*, *C*, *D*, or *E* is not the cause.

But, according to the Law of Causality, every event must have a cause. Therefore, *A* is the cause.

The deductive character of the Method of Difference may be shown by reducing it to a syllogism thus:—

Symbolical example:—

A B C	followed	by	*p q r*
B C	followed	by	*q r*

$\therefore$ *A* is the cause of *p*.

It may be reduced to the following syllogism :—

Whatever antecedent cannot be eliminated without prejudice to the effect is the cause ;

A cannot be eliminated :

$\therefore$ *A* is the cause.

In this way, the other Methods also may be shown to be of deductive character.

But though the Experimental Methods are at bottom *deductive* in character, they should not be called Deductive Methods. They are called Inductive Methods, because they enable us to pass from particular facts to a general law by discovering a causal connection between the two phenomena about which we make a general statement. The Inductive Methods are more methods of *proof* than of *discovery*.

25. Whewell's Criticism of the Inductive Methods.

Dr. Whewell questions the utility of Mill's Inductive Methods on the following grounds:—

(1) Firstly, Inductive Methods assume the very thing that is most difficult to discover, namely, *the reduction of concrete phenomena into formulæ.* They assume, for example, that A B C is followed by *p q r*, *B C D* is followed by *q r s*, and so on. But nature never supplies us with such clear-cut instances. The phenomena of Nature are too complex to be reduced to the neat formulæ of the Inductive Methods. They can be reduced to formulæ, only when their causes have already been discovered.

(2) Secondly, no *discoveries* were ever made by the application of the Inductive Methods.

Mill refutes both these charges. (1) To the first objection, he replies that, though it is very difficult to obtain such clear-cut instances as the Inductive Methods assume, still we must know the *forms* to which the complex phenomena of Nature have to be reduced for causal investigation. "The Experimental Methods provide us

with the rules or models to which if inductive arguments conform, those arguments are valid, and otherwise not." (*Mill*). And the Methods do not profess to be anything more than such rules or models.

(2) In answer to the second objection, Mill replies that if discoveries are made by observation and experiment they are made by processes which are reducible to one or other of the Inductive Methods. In other words, scientific discoveries are not, indeed, made by consciously following the Inductive Methods; still they do involve the employment of the Inductive Canons. Moreover, according to Mill, Logic is mainly concerned with proof as such, and the Inductive Methods are "the sole methods of Proof"; they do not profess to be methods of discovery. So, the second charge of Whewell is entirely groundless.

QUESTIONS

1. How are the Experimental Methods related to inductive reasoning?

2. State the principles of Elimination and explain their relation to the Experimental Methods.

3. State the Experimental Methods and deduce them from the ultimate postulate of Inductive Logic.

4. Enunciate and explain the canons or principles which underlie the Experimental Methods. Give concrete examples.

5. Deduce the Experimental Methods from the Law of Causation.

6. The Inductive Methods have been called the Weapons of Elimination. Discuss the appropriateness of this description.

7. "Mill's Inductive Methods are all reducible to one principle—the elimination of the inessential." Explain and discuss.

8. Explain and examine the following statement:—

"All Methods of Induction are Weapons of Elimination."

9. What is meant by 'varying the circumstances' in scientific investigation? What is the use of the process? Add illustrations to explain your meaning.

10. State the Method of Agreement, giving symbolical and real examples. What is its characteristic defect and how may it be overcome?

11. Show how in the Method of Agreement the multiplication of instances increases the probability of the induction.

12. Enunciate the Method of Agreement, pointing out its advantages and disadvantages. How are the disadvantages remedied?

13. Discuss the value of Mill's Method of Agreement, and consider how far it is affected by the "Plurality of Causes" and "Intermixture of Effects."

14. Explain the principle of the Method of Agreement.

15. Show exactly how Mill's Method of Agreement differs from Simple Enumeration. What are its defects and utility in scientific discovery?

16. Enunciate the canon of the Method of Difference. Show by the help of a concrete example why it is important that in applying this method only one circumstance should be altered at a time.

17. The Method of Difference is claimed to be in the nature of an experiment. Why? Give examples.

18. State in your own words and illustrate with symbolical and real examples the Method of Difference. Show by common instances that the Method plays a great part in every day inferences.

19. Explain and illustrate the Method of Difference, showing its close connection with experiment and practical life. Point out how a careless use of it leads to the fallacy of *post hoc ergo propter hoc.*

20. Give some instances of simple experiments fulfilling completely the conditions of the Method of Single Difference.

21. What advantages has the Method of Difference over the Method of Agreement and what advantages has the latter over the former ?

22. Compare the canons of Agreement and Difference as to the difficulty of finding or preparing actual instances for them and (2) as to their conclusiveness.

23. Explain why the Method of Agreement requires many instances while the Method of Difference is satisfied with one precise experiment. Why is the Method of Agreement of little value, as compared with the Method of Difference ?

24. When is a single instance sufficient to warrant a universal conclusion ? Are there cases where the greatest number of concurring instances without an exception is not sufficient to warrant such a conclusion ? If so, why so ?

25. What is the Joint Method ? Illustrate it by concrete examples. When is it necessary to use the Joint Method ? What is the special advantage of this Method ?

26. Give a brief account of the Joint Method and with the help of instances show what are its advantages as a scientific method.

27. State fully and clearly in your own words the Method of Concomitant Variations, with examples. On what canon or principle is it based ? Of what other Method is it a modification ? Is it a method of Observation or of Experiment or of both ? In what class of cases is it the only possible inductive method, and why ?

28. Explain and illustrate the Method of Concomitant Variations. What are the circumstances under which it is specially applicable?

29. When is it necessary to employ the Method of Concomitant Variations? Explain and illustrate this method, indicating its different forms.

30. Give a concrete example of the Method of Concomitant Variations. Indicate the limitations of this Method. Explain the principle of the quantitative equivalence of cause and effect.

31. "The Method of Concomitant Variations and the Method of Residues are modifications of the Method of Difference." Explain and illustrate the above statement. Explain the cases in which each of these methods is appropriately employed.

32. How does the Method of Difference differ from the Method of Residues?

33. Explain, giving a concrete example, the Method of Difference and point out its relation to the Methods of Concomitant Variations and Residues. Explain the nature of phenomena for the investigation of which the last two methods are particularly suited.

34. Can the Methods of Induction be reduced to one Method? Are they logically valid?

35. Explain the Method of Residues and indicate its special value in scientific investigation.

36. Show in what respects the Method of Difference, (*a*) agrees with, and (*b*) differs from, the Method of Residues.

37. Show that the specific problem of induction really begins where the Method of Residues leaves off.

38. Explain the principle on which the Method of Residues proceeds, and illustrate its importance in the history of science.

39. Can the Method of Residues be fairly considered inductive in character?

40. Show, by an example, that the Method of Residues involves the application of Deduction.

41. State the Method of Residues fully with examples, symbolical and concrete. Does it involve any element of Deduction? Show how it may lead to the discovery of new antecedents. Give some examples of this.

42. What are the two ways in which the Method of Residues may be applied?

43. Criticise Mill's "Experimental Methods," pointing out their value in Scientific Induction, and bringing out their defects.

44. Explain and illustrate the chief difficulties which tend to frustrate the Experimental Methods. How are they overcome?

45. How do Plurality of Causes and Intermixture of Effects frustrate the application of the Experimental Methods? And what are the remedies by which the difficulties created by them are overcome?

46. Show how Intermixture of Effects prevents the employment of the Experimental Methods. Do all the Experimental Methods fail in such a case? Give reasons for your answer.

47. Show by means of instances how the Method of Concomitant Variations is a peculiar application, or a series of applications, of the Method of Difference.

48. Explain and illustrate the principle of the method by which quantitative relations are established between a cause and its effect.

49. Discuss briefly Mill's "Inductive Methods", and distinguish the "methods of observation" from the "methods of experimentation". Illustrate your answer by means of examples.

50. 'Some inductive methods are adapted for *suggesting* causes, others for *testing* them.' Discuss. (The former are methods of discovery; the latter are methods of proof.)

51. 'The Method of Agreement is a Method of Discovery. The Method of Difference is a Method of Proof.' Explain the significance of this remark.

52. Explain what is meant by saying that the Methods of Agreement and Difference are mainly methods of observation and experiment.

53. Explain and illustrate the remark that 'the Method of Agreement is a Method of Discovery, while the Method of Difference is a Method of Proof.' Enumerate the advantages the former has over the latter, and the latter over the former.

54. In arguing from effect to cause what methods are available? (Methods of observation.) Is it always possible to trace back a given effect to one cause?

55. Analyse and describe in logical terms the method by which any important discovery of recent years was made.

56. Bring out the importance of the negative instance in the experimental methods and point out under what circumstances it ceases to be available.

CHAPTER VII

COMBINED INDUCTION AND DEDUCTION
THE DEDUCTIVE METHOD

1. The Necessity of the Deductive Method.

We have seen how the Inductive Methods are beset with many difficulties. There are difficulties of observation and experiment which supply the data of Induction. And there are the characteristic difficulties of the Inductive Methods, which affect their validity. These arise, as we have already seen, from Plurality of Causes, Conjunction of Causes, and Intermixture of Effects. All the Inductive Methods are not equally frustrated by Plurality of Causes. The Method of Agreement is most affected by Plurality of Causes. But, here, also, the defect can be remedied partly by multiplication of instances and completely by the Joint Method.

But all the Inductive Methods except the Method of Residues are affected by Conjunction of Causes and Intermixture of Effects. The Method of Residues can cope with Homogeneous Intermixture of Effects, if its parts are known to be effects of known causes. The other Inductive Methods can prove a causal connection between two simple phenomena, where a single cause produces a single effect. But they fail, if many causes co-operate to produce a joint effect. They cannot cope with Conjunction of Causes and Intermixture of Effects. We can explain

complex phenomena due to a conjunction of causes by the Deductive Method. It consists in the combination of Induction with Deduction.

2. The Deductive Method.

The Deductive Method consists in the alternate use of induction and deduction in order to explain exceedingly complex phenomena. It consists in the combination of induction and deduction to find out the causes of an Intermixture of Effects due to conjunction of causes. The pure Inductive Methods fail to cope with the task.

The Deductive Method takes two principal forms, *viz.*, (1) the *Direct Deductive Method* and (2) the *Inverse Deductive Method*. The first is also called the *Physical Method*. The second is also called the *Historical Method*.

3. The Direct Deductive Method or the Physical Method.

"The problem of this Method is to find out the law of an effect from the laws of the different tendencies of which it is the joint result." (*Mill*). The Direct Deductive Method is employed to investigate the causes of *homogeneous intermixture of effects*. It is usefully employed in physical sciences like Physics, Mechanics, Astronomy, etc. So, it is also called the Physical Method. It involves three steps, *viz.*, (1) ascertaining the laws of the separate causes by direct induction ; (2) deduction or ratiocination, or computation of the joint effect, and (3) verification.

(1) **Direct Induction.** The first step is the ascertainment of the laws of the various causes. When we are required to explain a complex effect, we should, first,

ascertain the sepatate *causes* and their *laws* which co-operate to produce the joint effect. Inductive Methods establish a causal connection between simple facts. Therefore, we can ascertain the separate causes and their laws which jointly produce the complex effect by direct inductions. If they fail to supply them, we should frame hypotheses about them. Thus we start with direct inductions to ascertain the separate causes and their laws.

(2) Deduction or Ratiocination.

The second step is ratiocination or deductive calculation of the joint effect of the laws of the separate causes known by direct inductions. We calculate the joint effect of the separate causes and their laws ascertained by previous inductions. This is the element of *Deduction* in the Direct Deductive Method.

(3) Verification.

The third step is verification of the calculated effect. It consists in comparing the deduced effect with facts of actual observation. The deduced joint effect must tally with facts of observation and experiment. If the calculated result tallies with actual facts, it is said to be verified.

Carveth Read sums up the different stages of the Direct Deductive Method in the following words. "Given any complex mechanical phenomenon, the inquirer considers—(1) what *laws* already ascertained seem likely to apply to it (in default of known laws, hypotheses are substituted); he then—(2) *computes* the effect that will follow from these laws in circumstances similar to the

case before him ; and (3) he *verifies* his conclusion by comparing it with the actual phenomenon."[1]

Each of the three stages is an essential part of the method. We cannot start our investigation unless we know some laws already established by the Inductive Methods. We start with these laws and deduce their joint effect. Then we verify the calculated result by comparing it with actual facts of observation and experiment. Without verification the Direct Deductive Method of Science would be indistinguishable from the Abstract Deductive Method of Geometry, in which we start with definitions, axioms and postulates and deduce conclusions from them. Geometry deals with abstractions or ideal concepts and their consequences. So the Geometrical Method does not require verification by comparison with concrete phenomena.

Examples.

(1) We are required to explain the path described by a *projectile*. First, we ascertain the separate causes and their laws. We know by previous inductions that three forces are operative in this complex phenomenon. (*i*) There is the force of gravity, which tends to make the body fall to the earth. (*ii*) There is the force of the projectile which tends to make it move in a straight line. (*iii*) There is the resistance of the air which tends to diminish its velocity. The laws of these forces are known to us by previous inductions. Secondly, we calculate the joint effect of these three forces co-operating together by

1 *Logic* p. 240.

deduction. We find with the help of our knowledge of mathematics that the path, a projectile should describe, is a parabola. Thirdly, we verify the deductive calculation by observation and experiment. We compare the calculated result with facts of actual experience. We make experiments with balls and such other things. We throw them upwards, and find that they describe a parabola before they reach the earth. Thus deduction is verified by observation and experiment.

(2) We are required to explain the rise of water in the common pump. First, we ascertain the separate causes and their laws. We know by previous inductions that three laws are operative here. (*i*) The atmospheric pressure on a column of water is 15lb. to the square inch. (*ii*) Liquids (*e. g.*, water) transmit pressure equally in all directions (*i. e.* upwards, downwards and sideways). (*iii*) Pressure in any direction, if not counteracted by an opposite pressure, produces motion. Secondly, we calculate the joint effect of these laws. When the piston of the pump is raised, it removes the pressure upon the water within the cylinder and tends to produce a vacuum ; the pressure of the air outside the cylinder forces the water to rise up and follow the rising piston. Thirdly, we verify the calculated result. We actually find that at the sea level water can be pumped to the height of 33 ft., which has a pressure of 15lb. to the square inch. Thus the calculated result is verified by observation and experiment.

Carveth Read emphasises the need of verification in the deductive investigation by indicating the sources of error in it. Sometimes the joint effect deduced from the

concurrent causes assumed does not correspond with the observed facts. This shows that there must be error somewhere. Carveth Read says: "If the fact has been accurately observed, the error must be either in the process of deduction and computation, or else in the premises. As to the process of deduction, it may be very simple and easily revised; or it may be very involved and comprise long trains of mathematical calculation. If, however, on re-examining the computations, we find them correct, it remains to look for some mistake in the premises. (1) We may not have accurately ascertained the *laws*, or the modes of operation, or the amounts of the forces present. (2) The *circumstances* in which the agents are combined may not have been correctly conceived. (3) One or more of the *agents* affecting the result may have been overlooked and omitted from the estimate. (4) We may have included among the data of our reasonings *agents* or *circumstances* that do not exist or do not affect the phenomenon in question."[1]

By means of the Direct Deductive Method we can answer two questions. (1) Given a certain combination of causes what effect will follow? (2) What combination of causes would produce a given effect? A combination of causes is given, and we may deduce their joint effect. Or, a complex effect is given, and we may find out its causes acting together. J. S. Mill claims a high value for this Deductive Method. He says: "To this Deductive Method the human mind is indebted for its most conspicuous triumphs in the investigation of nature. To it we

1 *Logic*, pp. 243—45.

owe all the theories by which vast and complicated phenomena are embraced under a few simple laws which, considered as the laws of those great phenomena, could never have been detected by their direct study." Bain says, "Combined Induction and Deduction expresses the full force of scientific method for resolving the greatest complications." What Mill has called the Deductive Method Jevons calls the **Combined or Complete Method,** which consists in the alternate use of induction and deduction. It is very difficult to apply this method to complex phenomena of nature. It requires very subtle and accurate analysis and synthesis. It requires the alternate use of induction and deduction, each of which may be vitiated by errors. But if we can avoid errors in induction and deduction, we can explain extremely complicated phenomena of nature by this method.

4 The Inverse Deductive Method or the Historical Method.

In the Direct Deductive Method, we have seen, we start with certain causes or laws ascertained by previous inductions, deduce their joint effect by ratiocination, and then verify the calculated result by observation of actual facts. But there are certain enquiries (*e. g.*, social, historical, or political) to which from their extremely complicated nature, the Direct Deductive Method is altogether inapplicable.

The forces that operate in social phenomena are so intricate, so complicated, and so numerous, that it is

impossible to calculate their joint effect by ratiocination or deduction. In such cases we resort to the *Inverse Deductive Method*. It is also called the *Historical Method* as it is most effectively employed in History, Politics, Economics, Sociology, etc.

In the Historical Method we start with certain *empirical laws* based on observation of facts of social life, and then *deduce* these laws from the known "higher principles of the human nature." The Inverse Method consists in making empirical laws after an observation of facts of social phenomena, and then verifying them by deduction from some accepted higher laws. It consists of two steps :—

(1) Empirical Generalisation.

We observe a large number of social phenomena we want to explain, and reach an empirical law. We do not employ the Inductive Methods because they are totally inapplicable to such extremely complex phenomena. We make an empirical generalisation on the strength of the observation of actual facts.

(2) Deduction.

Then we verify the empirical law by *deduction* from higher laws. We deduce it from the known higher principles or from "the nature of the case." Thus, an empirical law or induction is verified by deduction.

Examples.

(1) We want to explain the Revolution in Russia. We observe many political revolutions, and make an empirical generalisation : "the tyranny of an absolute

monarch is the cause of revolution." Then we verify it by deducing it from the laws of human nature: People brook oppression of an absolute monarch for a long time; but when it reaches the breaking point of their patience, they cannot but revolt. The empirical generalisation is verified by deduction.

(2) We find that the military state has certain specific characters, in Russia, Germany, and Italy; we know it by empirical generalisation. In a military state there is enormous growth of the warrior class; labourers exist for the support of the warriors; all individuals are subordinated to the will of the despotic soldier-king; their property, liberty and life are at the service of the State; all private associations are suppressed; society is regimented not only for military but also for civil purposes. *The specific characters of a military State can be deduced from their utility for the purpose of war.* The chief purpose of a military State is war. So a vast army has to be organised. Labourers must be enlisted in the army. Those who work in farms and factories must feed and equip the soldiers. As this arrangement is not liked by the majority, there must be despotic control. Private associations have wills of their own and may conspire against the State; so they are suppressed. Individuals' liberty of speech is suppressed; their life and property are commandeered by the State for vast military operations. Thus the empirical law regarding the characteristics of a military State is verified by a deduction from the higher laws or "from the nature of the case."[1]

1 Carveth Read: *Logic*, p. 257.

(3) We observe a large number of peasant proprietors in France, Germany, Norway, Belgium, etc., and make an empirical law : "peasant proprietors are extremely industrious and prudent." We verify this empirical generalisation by deduction from higher laws. Their industry is due to the fact that the whole produce of their land belongs to them. Their prudence is due to the fact that by saving they can improve their land and add to their income.

The Historical Method is essential to the discovery of causes of social phenomena. They are too complicated to be investigated by the Physical Method. Here we cannot start with laws established by the Inductive Methods. We have to start with Inductions by Simple Enumeration or Empirical Generalisations, and deduce them from "the nature of the case." "Wherever the forces determining a phenomenon are too numerous or too indefinite to be combined in a deductive demonstration, there the Historical Method is likely to be useful ; and this seems often to be the case in Geology and Biology, as well as in the Science of History, or Sociology, and its various subsidiary studies."[2] The Historical Method is liable to be more vitiated by errors than the Physical Method owing to the extremely complicated nature of its subject matter. It requires great sagacity and insight into human nature and social forces.

5. Comparison of the Direct Deductive Method and the Inverse Deductive Method.

The Inverse Deductive Method is distinct from the Direct Deductive Method, though both involve the com-

2 *Ibid*, p. 248.

bination of induction with deduction. In the former, we verify deduction by observation and experiment which are inductive processes, while in the latter we verify empirical generalisations or inductions by simple enumeration by deduction: In the former, we compare the results of deductive calculation with observed facts, while in the latter we start with empirical generalisations based on observation of facts, and then verify them by deducing them from the higher laws of human nature. In other words, in the former, a Deduction is verified by an Induction (observation or experiment), while in the latter an empirical generalisation or Induction is verified by Deduction. In the former Deduction precedes Induction (observation or experiment), while in the latter Induction precedes Deduction. "Whereas in the Direct method we compare the results of deductions with observed facts, in the Inverse Method, we begin by provisionally formulating empirical laws gathered from facts of observation, and then verify these laws by deducing them from the accepted principles." (*Gibson*). The Inverse Method is more indefinite than the Direct, both in its inductions and deductions, owing to the extremely complicated nature of its data.

Carveth Read objects to the distinction between the Direct Deductive Method and the Inverse Deductive Method on the ground of mere order of occurrence of Induction and Deduction in them. In the first place, in complex investigations Induction and Deduction may recur again and again in whatever order may be most convenient. In the second place, the Inverse Deductive

Method also is sometimes employed in Astronomy and Physics. Kepler's laws of planetary motions were first empirical laws gathered from the observations of the movements of planets. They were later deduced by Newton from the Law of Gravitation. This was the Inverse Method; but the result is much more definite and accurate than any that can be obtained by the Historical Method. Likewise, the Physical Method is sometimes applied to the study of historical facts. Therefore, Carveth Read distinguishes between them on the ground of the accuracy or inaccuracy of their conclusions. He says: "The essential difference between the Physical and Historical Methods is that, in the former, whether Direct or Inverse, the deductive process, when complete, amounts to exact demonstration; whereas, in the latter, the deductions may consist of qualitative reasonings, and the results are indefinite."[1]

Besides the Physical Method and the Historical Method there are two other minor methods, *viz.*, the Geometrical Method and the Hypothetical Method.

6. The Geometrical Method.

The Direct Deductive Method and the Inverse Deductive Method both combine Induction with Deduction though in different order. Hence Jevons calls them the *Combined* or *Complete Method.* They deal with concrete phenomena. So they are also called the *Concrete Deductive Method.* But the *Abstract Deductive Method* or the Geometrical Method does not use Induction at all,

1 *Logic*, p. 247.

but uses Deduction only. It starts with definitions, axioms and postulates, and deduces conclusions from them. It deals with *abstractions*, and not with concrete phenomena. For example, it first defines a triangle as a plane figure bounded by three straight lines. Then it deduces the properties of a triangle from this definition such as its three angles are equal to two right angles; its two sides are together greater than the third side, and so on. Here the triangle is an abstraction. It is not identical with triangular things in nature. Therefore there are no counteracting agencies here. The Geometrical method is deductive, pure and simple, and has no place in the investigation of the phenomena of nature. It does not require verification. In pure mathematical reasoning there is no need of verification, if the premises and reasoning be correct, because there is no possibility of counteraction. In the Geometrical Method deductions from ideal concepts cannot be compared with actual facts. But still some thinkers erroneously apply the Geometrical Method to concrete phenomena in Politics, Ethics, Philosophy, etc.

7. The Hypothetical Method.

In the Direct Deductive Method we start with separate causes and laws which are *proved* by previous inductions. But when we cannot obtain laws from previous inductions, we *assume* some laws which may be operative in the production of the complex phenomenon under investigation. This is called the Hypothetical Method. It consists of three steps: (1) Framing of Hypotheses; (2) Deduction of their joint effect; (3) Verification of the deduced effect

by observation or experiment. The Hypothetical Method is often employed in inductive investigations. We have already discussed the nature and conditions of valid hypotheses.

8. The Relation between Induction and Deduction.

The relation between Induction and Deduction is not one of opposition, but of interdependence. Though Deduction consists in applying a general principle to particular cases, and Induction consists in deriving a general principle from particular cases, they are not opposed to each other. They are interdependent on each other. The syllogism is a type of Deduction. But the universal premise of a syllogism, without which it is not possible cannot ultimately be derived from Deduction. It is a generalisation from previous Induction. Thus, Deduction presupposes Induction. Induction also presupposes Deduction. Induction involves the application of the Inductive Methods which are deductions from the Law of Causation. The Inductive Methods are based on certain principles of elimination which are deduced from the Law of Causation. The Law of Causation is involved in the Uniformity of Nature. Thus, all inductive arguments may be reduced to the syllogistic form with the Uniformity of Nature as the major premise. Let us reduce the following Inductive argument to a syllogism thus :—

John is mortal,
Jones is mortal,
James is mortal ; and so on ;
∴ All men are mortal.

Whatever is true of John, Jones, James, etc., is true of all men ;

Mortality is true of John, Jones, James, etc ;

∴ Mortality is true of all men.

Thus, Deduction and Induction are two *aspects* of the same process. They are interdependent on each other.

Generally, Deduction and Induction are combined together in the scientific investigation of extremely complex phenomena. In the Direct Deductive Method, Deduction is verified by Induction (*i. e.*, observation or experiment), while in the Inverse Deductive Method, Induction (empirical generalisation) is verified by Deduction. Thus, Deduction and Induction are supplemented and verified by each other. Still their essential difference should not be overlooked.

9. Different Views on the Relation between Induction and Deduction.

(1) **Mill.**—*Induction is prior to Deduction.* Induction always precedes Deduction. By Induction we first arrive at universal principles, and then apply them to particular cases by Deduction. The universal premise of a syllogism is supplied by Induction. In fact, Deduction (Syllogism) as a method of argument involves the fallacy of *petitio principii*. Deduction is simply a means to the verification of inductive generalisation by applying them to particular cases. Venn describes the following views of the relation between Induction and Deduction.

(2) **Jevons.**—*Deduction is prior to Induction*; *Induction is the inverse process of Deduction.* Deduction always

precedes Induction. At first, a universal proposition is suggested to the mind by imaginative insight as a hypothesis, and then it becomes an Induction, when it is verified by observation of facts. Thus, verification *i. e.*, deduction of facts from a hypothesis or universal proposition precedes inductive generalisation. In other words, Deduction precedes Induction. Induction is the inverse process of Deduction, because in Deduction the premises are given, and the conclusion has to be obtained; while in Induction the conclusion is given in the form of a hypothesis, and the premises have to be obtained in the form of particular facts which fit in with the hypothesis.

(3) **Bacon.**—*Induction is an ascending process, while Deduction is a descending process.* By this Bacon means that in Induction we rise from *particular* facts to *general* laws while in Deduction we come down from *general* laws to *particular* facts.

But this is only a metaphorical way of describing the relation between Induction and Deduction. In processes of thought there is neither ascent nor descent.

(4) **Fowler.**—*In Induction we proceed from effects to causes, while in Deduction we proceed from causes to effects.*

This statement is only partially true, for both in Deduction and in Induction we may as well proceed from causes to effects as from effects to causes.

(5) **Buckle.**—*In Induction we reason from facts to ideas while in Deduction we reason from ideas to facts.* This means that Induction and Deduction respectively involve generalisation from individual observations, and specialisa-

tion to narrower, and even to individual results, from given generalisations.

This view is partially true. In Induction we more often reason from facts to facts than from facts to ideas, and also in Deduction we sometimes reason from ideas to ideas.

(6) **Other Logicians.**—*Induction is Analysis while Deduction is Synthesis.* But Analysis and Synthesis are used in a far wider sense ; they are general processes, and are not confined to Induction and Deduction only. All that we can say is that Induction makes more use of Analysis than Deduction does.

QUESTIONS

1. What are the limitations of Mill's Experimental Methods ? Show how some of these are overcome by the Deductive Method.

2. Explain the nature of the Deductive Method and show when it is applied. What are its merits ?

3. By what method can the difficulty arising from Intermixture of Effects be completely overcome ? Describe and illustrate the method fully.

4. Describe the different steps in the Direct Deductive Method and explain their interrelation.

5. Why is the Direct Deductive Method employed in inductive investigation ? How is it related to Hypotheses ? Explain and illustrate the Historical Method of sociological enquiry.

6. Distinguish between the Direct Deductive Method and the Inverse Deductive Method. Give concrete examples. Why have they been called the Physical and the Historical Methods respectively ? Are the names quite appropriate ?

7. Indicate the aid given to Induction by Deduction.

8. Show how Induction and Deduction are supplemented by each other in scientific investigation.

9. Discuss the part played by deductive reasoning in inductive enquiry.

10. Why are social phenomena so difficult to treat scientifically? What methods may be employed in treating them?

11. Mill and Bain think that three operations are employed in the full scope of the Deductive Method, *viz.*, Induction, Deduction proper, and Verification. Explain the exact meaning of each, and exhibit their relation to one another, making your meaning clear, by means of examples.

12. Explain the remark:—

"Deduction and Induction are continuous operations."

13. Induction is sometimes described as an '*inverse* process of deduction.' Clearly explain and illustrate the statement.

14. Explain your view of the relation of Induction to Deduction. Which of these is the prior process and on what grounds do you think it to be so?

15. Is Inductive Reasoning merely the converse of Deductive Reasoning? Fully discuss the question, and bring out clearly the relation between them.

16. "Induction gives us principles; deduction applies them."

Do you consider this an adequate statement of the relation between deduction and induction? If so, explain and illustrate it; if not, show wherein it is deficient.

CHAPTER VIII

ANALOGY

1. Introduction.

Inductions are divided, according to the Scholastic Logicians, into Perfect Induction and Imperfect Induction. Imperfect Inductions are divided into Complete Induction and Incomplete Induction. We take Complete Induction in the sense of an inference from particular truths to a general truth. We take Incomplete Induction in the sense of an inference from particular truths to another particular truth. Analogy and Probability are Incomplete Inductions. In both we reason from some known particulars to an unknown particular. We shall discuss the nature and value of Analogy in this chapter. We shall treat of Probability in the next chapter. Complete Inductions are of two kinds, *viz.*, Induction by Simple Enumeration and Scientific Induction. We have discussed the nature of both. We have considered the formal and material grounds of Scientific Induction, the Inductive Methods, and the Deductive Methods which establish a causal connection on which it is based. Let us trace the history of Analogy as a method of proof.

2. Various Meanings of 'Analogy'.

Aristotle meant by Analogy '*an equality or identity of*

ratios' or *proportion*. The inference, according to him, is of the following character:—

$2 : 4 : : 3 : 6.$

$a : b : : c : d.$

The ratio between 3 and 6 is identical with the ratio between 2 and 4. Here the terms are quantities and the relations between them also are quantitative. If in respect of weight $a : b : : c : d$, and if a weighs twice as much as b, then c must weigh twice as much as d. Thus, if we infer from the relation $a : b : : c : d$ that what is true of the relation between a and b is also true of that between c and d, we are said to argue from analogy. The relation between c and d is *analogous* to that between a and b. Here analogy means identity of ratios.

From proportions of numbers we pass to other proportions in which the terms are not homogeneous or of the same kind. Analogy is taken in the sense of *identity of relations*. For example:—

Health : Body : : Virtue : Soul.

As health is to the body, so is virtue to the soul. The relation of health to the body is *analogous* to the relation of virtue to the soul. Health is the harmony of the body. So virtue is the harmony of the soul. Here also there is the idea of proportion.

Whately defines Analogy as *resemblance of relations*. It is not simply resemblance of quantity. It is a resemblance of *quality*. The relation of the mother country to the colonies is *analogous* to the relation of the mother to her children, So, the colonies should be obedient to

the mother country as the children should be obedient to the mother. The relation of the king to his subjects is analogous to that of the father to his children. So, the subjects should obey the king as the children should obey the father. Here analogy is resemblance of relations.

Analogy, in the **modern** sense, is an argument from some degree of resemblance to a further resemblance. It is an inference based on resemblance between two things. It is of the following form:—

A and B resemble each other in properties, p, q, r,...
A possesses a certain other property x;
∴ B also possesses the property x.

Two things resemble each other in certain respects. Therefore they will resemble each other in some other respect.

3. The Nature of Analogy.

In modern Logic, Analogy is an inference from one instance to another which resembles it in certain respects. **Mill** says. "Two things resemble each other in one or more respects ; a certain proposition is true of the one; therefore it is true of the other."[1] **Bain** says: "Analogy, as different from Induction, and as a distinct form of inference, supposes that two things from resembling in a number of points, may resemble in some other point, which other point is not known to be connected with the agreeing points by a law of causation or of co-existence."[2] **Welton** says: "Analogy is an inference from partial identity of content to further identity of content."[3]

---

1 *Logic*, III,XX, § 2. 2 *Logic*: *Induction*, p. 143.
3 *A Manual of Logic*, Vol. II, p. 75.

Carveth Read defines "Analogy as a kind of probable proof based upon imperfect similarity between the *data* of comparison and the subject of inference."[1]

(1) Analogy is a kind of Incomplete Induction. It is an inference from one particular to another particular. It is an inference from *some* to *some*. It falls short of a general proposition. Therefore, it is sometimes called an Incomplete Induction.

(2) It is based on *imperfect similarity*. It assumes that two things resemble each other in certain respects, and therefore they will resemble in some other respect. A and B resemble each other in certain properties, *m*, *p*, *q*, *r*. A further possesses *x*. So B also may possess *x*.

(3) It is a *probable* proof. It is based on imperfect similarity. So it cannot yield a certain conclusion. No causal connection is established between the ground of inference and the inferred property by the Experimental Methods in an analogical argument.

(4) Its value depends upon the *number* and *importance* of the points of resemblance. The more numerous and important are the points of similarity, the more probable is the conclusion.

For example, Mars resembles the earth, (1) in being a planet, (2) having an atmosphere, (3) being neither too hot nor too cold for life, (4) having land, water, etc. The earth is inhabited by living beings. So Mars also may be inhabited by living beings. Here we do not know any causal connection between the properties common to the Earth

1 *Logic*, p. 307.

and Mars and the presence of life. If a causal connection is established between them, analogy will become an Induction.

4. The Grounds of Analogy.

According to **Mill**, "The value of an analogical argument depends on the *extent of ascertained resemblance*, compared first with the *amount of ascertained difference*, and next with the *extent of the unexplored region of unascertained properties*; it follows that where the resemblance is very great, the ascertained difference very small, and our knowledge of the subject-matter tolerably extensive, the argument from analogy may approach in strength very near to a valid induction. If, after much observation of *B*, we find that it agrees with *A* in nine out of ten of its known properties, we may conclude with a probability of nine to one, that it will possess any given derivative property of *A*."[1] **Mill** emphasises the *amount of resemblance* compared with the amount of difference and unknown properties as the ground of analogical argument. The greater the number of the points of similarity, the more probable the conclusion. The greater the number of the points of difference, the less probable the conclusion. And the greater the number of unknown properties, the less probable the conclusion. "The value of an argument from analogy ranges from certainty to zero. If it reaches certainty, the argument becomes a complete induction; if it falls to zero, it ceases to be an argument at all"[2] (*Fowler*). Analogy is based upon imperfect

1 *Logic*, III, XX, § 3.

2 *The Elements of Inductive Logic*, 6th edition, p. 233.

similarity. So its conclusion is probable, and probability is a matter of degrees. The value of an analogical argument has been expressed by a *fraction* as follows:—

$$\frac{\text{Resemblance}}{\text{Difference} + \text{Unknown properties}}$$

The numerator consists of elements of strength. The denominator consists of elements of weakness. The fraction roughly indicates the conditions of an analogical argument. Resemblance strengthens it ; and difference and unknown properties weaken it. But the fraction does not indicate a mathematical ratio. For example, the argument that Mars is inhabited by living beings is a better argument than that the moon is inhabited by living beings, because the number of resemblances between Mars and the Earth is greater than the number of resemblances between the moon and the earth. In the case of the moon there is a great difference that it has no atmosphere. On the other hand, the analogy between Mars and the Earth is weakened by the fact that our knowledge of Mars bears very small proportion to our ignorance.

Criticism of Mill's view.

(1) Mill lays stress on the *number* of resemblances and differences and unknown properties. He seems to think that the value of an analogical argument depends on the *amount* of similarity. But **Welton** rightly observes: "The force of an argument from Analogy depends upon the *character* of identity, and not upon the *amount* of similarity."[1]

1 *A Manual of Logic*, Vol. II, p. 78.

Mere number of points of similarity does not count much. Two objects may resemble each other in a very large number of unimportant qualities. But they may not justify us in inferring resemblance in any other quality. For instance, two boys may resemble each other in height, bulk, weight, complexion, and strength ; they may be of the same age, born in the same town, belong to the same caste, and read in the same school ; one of them is very intelligent ; therefore, the other also may be very intelligent. This analogical argument is worthless because none of the points of resemblance are *essential*. Hence, **Bosanquet** rightly says : "We must *weigh* the points of resemblance, not simply *count* them." Likewise, we must weigh the points of difference rather than count them. **Mellone** rightly says: **"The resemblances must be essential the differences unessential."**[1] Mill failed to realise that mere *number* of points of resemblance and difference is of little weight compared with the *quality* of the resemblance and difference. There is a large amount of resemblance between the Earth and the moon. But there is an essential difference. There is no atmosphere in the moon. We know that air is an essential condition of life. So the argument that the moon is inhabited by living beings like the Earth is worthless. Here the difference is essential ; so it can override a large amount of resemblance. "If the points of resemblance are essential, the points of difference may be disregarded ; and similarly, if the points of difference are essential, no amount of

1 *An Introductory Text-Book of Logic*, p. 262.

resemblance in other points will make the inference a safe one."[1] (*Welton*).

(2) The points of resemblance and difference cannot be counted in terms of units. We cannot decide as to whether a given point of resemblance or of difference is one 'property' or a dozen. If two persons resembie each other to some extent, we cannot analyse this resemblance into so many distinct points. Should we take taste for philosophy as one point or more ? Should we take æsthetic taste as one point or more ? It is very difficuit to decide it.

(3) When Miil refers to the *extent* of the unexplored region of the *unascertained* properties he contradicts himself. How can we count the *number* of *unknown* properties ? If properties are unknown, how can we know their number ? To speak of the number of unknown properties is to fall into a contradiction in terms.

Bain recognises the *importance* of the points of agreement and difference in addition to their number. He says, "An argument from Analogy is probable. The probability is measured by comparing the *number* and *importance* of the points of *agreement* with the *number* and *importance* of the points of *difference*; having respect also to the *extent* of the *unknown properties*, as compared with the known."[2] A property is important, if it is productive of other properties.

1 *A Manual of Logic*, Vol. II, p. 80.

2 *Logic: Induction*, p. 143.

Carveth Read also follows Bain. He gives the following conditions of an analogical argument:—

(1) "The greater the *number* and *importance* of the points of *agreement*, the more probable is the inference."[1] Men and anthropoids resemble each other in many important points. Men are intelligent. So anthropoids also may be intelligent. The analogical argument has great probative force.

(2) "The greater the *number* and *importance* of the points of *difference*, the less probable is the inference."[1] Men and earth-worms differ from each other in numerous important points. So the analogical argument that earth-worms are intelligent like men is very weak. The moon differs from the Earth in essential points. It has no atmosphere which is an essential condition of life. So the analogical argument that the moon is inhabited by living beings like the Earth is very weak.

(3) "The greater the *number* of *unknown* properties in the subject of our argument, the less the value of any inference from those that we do know. The number of unknown properties can itself be estimated only by analogy."[1] Our knowledge of Mars is very limited. Its unknown properties are probably very numerous. There appear to be canals in Mars. If they are really canals, there must be intelligent beings in Mars. But we are not sure of this fact. Our ignorance about Mars is greater than our knowledge of it. So the analogical argument that Mars is inhabited by living beings is not very strong,

1 *Logic*, p. 309.

though it is stronger than the argument that the moon is inhabited by living beings.

Here two different principles are involved, *viz.*, *number* and *importance* of resemblance and difference. Importance should outweigh number. If there is essential similarity, a large number of superficial differences will not count. And if there is essential difference, a large amount of superficial resemblance is of little weight. If there is a conflict between number and importance, we must decide in favour of importance.

5. Cautions to be observed in Analogical Argument.

Fowler lays down the following cautions to be observed in an analogical argument :—

(1) First, "we have no evidence that there is any causal connection between the new property and any of the known points of resemblance or difference." If we have such evidence, the argument ceases to be analogical, and becomes an induction. We can arrive at a general law on the strength of such evidence.

(2) "Secondly, though there must be no evidence to connect the property in question with any of the known points of resemblance or difference, there must, on the other hand, be no evidence to disconnect it." If we have such evidence, we must leave out of account the point of resemblance or difference which is known to be disconnected with the inferred property.

(3) "Thirdly, we must have no reason to suspect that any of the known points of resemblance or difference

are causally connected with each other." If we have such evidence, we must leave out of account those points of resemblance or difference which are said to be the effects of others.

(4) "Fourthly, it is only when we have reason to suppose that we are acquainted with a considerable proportion of the properties of two objects, that the argument from analogy can have much weight."[1] If we know only a few properties out of a large number, they may happen to be exceptional rather than representative, and we may note only similarities between the two objects which are mainly dissimilar, or do the reverse.

6. Analogy and Induction.

Analogy and Scientific Induction both proceed from the *known* to the *unknown*. In the Scholastic sense, both are kinds of Imperfect Induction. Both are based upon *similarity*; both assume that things alike in some respects are alike in others.

But Analogy is an *Incomplete* Induction, while Scientific Induction is a *Complete* Induction. Analogy is an inference from *particulars* to *particulars*, while Scientific Induction is an inference from the *particular* to the *general*. In Analogy we observe resemblance between two things in certain respects, and therefore infer that they will resemble each other in some other respect. In Scientific Induction we observe some particular facts and arrive at a general law of connection among them. In Analogy we proceed from one particular

1 *The Elements of Inductive Logic*, pp. 229—32.

to another particular without the help of a general law. Scientific Induction is based upon *perfect similarity* or community in essence among the particular facts observed. But Analogy is based upon *imperfect similarity*. Scientific Induction is based upon the Law of Causation. A *causal connection* is proved in it by the Experimental Methods. But in Analogy no causal connection is known to exist or established by the Experimental Methods. Scientific Induction is based on the uniformity of causation, while Analogy is based on mere co-existence. In Analogy no causal connection is known to exist between the ground of inference and the inferred property. But Scientific Induction is not possible without establishment of a causal connection. Therefore, Analogy is more or less *probable*, while Scientific Induction is *certain*. Probablity is a matter of degrees. So the probability of the conclusion of an analogical argument ranges from zero to certainty. But it can never reach the certainty of Scientific Induction.

7. Analogy and Induction by Simple Enumeration.

Analogy is a kind of *Incomplete* Induction. It is an inference from one particular case to another on the basis of imperfect similarity between the two cases. In this process of inference we proceed from the *particular* to the *particular*. But in Induction by Simple Enumeration we infer a general proposition from many particular facts. In this process of inference we observe a large number of particular facts and reach an empirical generalisation. It is an inference from the *particular* to the *general*. It is a *Complete* Induction.

Analogy is based upon *imperfect similarity* between *two* particular instances. But Induction by Simple Enumeration is based upon *uniform and uncontradicted experience* of a *large number* of facts. We observe that Mars resembles the Earth in many respects. Therefore we infer that Mars is inhabited like the Earth. This is an analogical argument. We observe a large number of black crows. Therefore we infer that "all crows are black." This is an Induction by Simple Enumeration.

Induction by Simple Enumeration depends upon mere counting of a *number of instances*. But Analogy depends upon counting of a *number of points of resemblance*; it depends upon the *number* and *importance* of points of resemblance ; it depends upon the *amount* as well as the *character* of resemblance. Analogy goes beyond Induction by Simple Enumeration because it analyses the two things that it compares, while the latter is generally unanalytical. Enumerative Induction is said to deal with the *denotation* of a term. Analogy is said to deal with the *connotation* of a term. The former counts the number of *instances*. The latter counts and weighs similar *qualities*.

In both Analogy and Enumerative Induction a *causal connection* is not established between the ground of inference and the inferred property by the Experimental methods. "While enumeration merely suggests that there is some connection, analogy often suggests the nature of the connection and the basis of it."[1] And the reason of this is obvious. Enumeration is *unanalytical*, while Analogy is *analytical*.

---

1 *Elements of Logic*, p. 313.

Both Analogy and Enumerative Induction yield *probable* conclusions, because they do not establish a causal connection. They are not valuable as methods of proof. But they are important sources of *discovery.*

8. Relation of Analogy to Induction.

In the Inductive Method we frame a hypothesis at the outset by observing a large number of facts. Then we verify the hypothesis by the Experimental Methods. The hypothesis, when thus verified, becomes an Induction. But a hypothesis is sometimes suggested by Analogy. Thus, Analogy plays an important part in Induction. It is a source of discovery. It is an inadequate method of proof. In the words of Mill, it is "a mere guide-post, pointing out the direction in which more rigorous investigations should be prosecuted."

9. Is Induction reducible to Analogy ?

Mill holds that all reasoning is ultimately reducible to analogy ; it is ultimately an inference from particulars to particulars ; it is of the form that because two objects resemble each other in certain points they will resemble each other in certain other points. He holds that general propositions are mere summations of particular propositions. In a syllogism usually we are said to deduce a particular proposition from a general proposition. In induction we are said to infer a general proposition from particular propositions. But because a general proposition is a mere summation of particular propositions, *all reasoning is really from particulars to particulars.* Thus, the type of all reasoning is of the form that because

A_1 is x, therefore A_n is x—the argument being based on the resemblance between A_1 and A_n in other respects.'

Criticism.

But this view is untenable. All reasoning, deductive and inductive, cannot be reduced to analogy. In Deduction we usually pass from a general proposition to a particular proposition, and not from one particular to another; a general proposition cannot be regarded as a mere summation of particular propositions. In Induction we pass from particular propositions to a general proposition which is not a mere shorthand summary of particular propositions. Both Deduction and Induction appeal to a general law. In Deduction it is supplied by the universal premise. In Induction it is supplied by the Law of Causation. But analogy does not imply any general law. Deduction and Induction both depend upon perfect similarity. But Analogy depends upon imperfect similarity. So all reasoning cannot be reduced to analogical argument. Induction, therefore, cannot be reduced to Analogy.

10. Analogy and Deduction.

Analogy is an inference from *particulars* to *particulars*; it is an argument from ascertained resemblance between two things to further resemblance. Deduction is an inference from the more general to the less general, or from the *general* to the *particular*. Deduction implies a general law in the form of a universal premise, while Analogy does not. Deduction is based upon *perfect similarity* or community in essence, while Analogy is

based upon *imperfect similarity.* The conclusion of deductive inference is *certain*, while the conclusion of analogical argument is *probable.* Both kinds of inference depend upon resemblance.

11. Analogy and Hypothesis.

Analogy is a source of discovery. It very often suggests hypotheses. Many important laws were first suggested by analogy. The analogy of a falling apple suggested to Newton the Law of Gravitation. The resemblance between lightning and electric spark suggested to Franklin their essential identity as forms of electricity. Galileo observed that four satellites revolve round Jupiter. So he inferred that planets also move round the Sun. The analogy of light suggested to Huyghens that heat is a form of motion ; this theory was established by Joule much later. The analogy between sound and light suggested that light, like sound, traveiled in waves. The analogy of competition in industry suggested to Darwin the Law of Natural Selection among the species. Even false hypotheses suggested by analogies guided scientists in their investigations and ultimately led them to the right laws. Kepler tested and rejected nineteen wrong hypotheses before he could discover the right law of the movements of pianets, and they were mostiy suggested by wrong analogies. Thus, analogies have been a great aid to scientific investigation.

12. Uses of Analogy.

(1) Analogy has an important function in Induction. In Induction we first collect particular facts and then

frame a *hypothesis.* And a hypothesis is sometimes suggested by *Analogy.* Analogy, therefore, is a source of *discovery.* The hypothesis suggested by Analogy is afterwards verified by the Experimental Methods and is exalted to the rank of an Induction.

(2) Analogy is not only a source of discovery but also a means of proof. Though it is a fruitful source of discovery, it is a *precarious* method of *proof.* The conclusion of an analogical argument is *probable*, since it is based upon imperfect similarity and not proved by the Experimental Methods.

(3) It suggests many plans in practical life. The resemblance of the Australian hills to the Californian hills led the miners to dig for gold.

(4) It is in constant use in daily life and literature. The use of examples, similes and metaphors illustrates the value of Analogy. In some sciences we cannot get beyond analogy and can have only probable proof.

13. Fallacies incident to Analogy.

False analogy arises from irrelevant comparisons which arise from the following :—

(1) *Wrong estimation of the force of Analogy.*

This generally occurs when we lay greater stress on the points of similarity and ignore the points of difference. We commit the fallacy of false analogy, when we argue that a nation, like an individual, passes through birth, growth and decay. Here the comparison is irrelevant; the likeness palpably fails in the most important points. A nation's losses are repaired, but the physical losses of a

human being due to old age cannot be repaired. Moreover, an individual has life, but a nation has no life of its own. Bacon committed the fallacy when he argued: "No body can be healthy without exercise, neither natural body nor body politic; and certainly to a kingdom or State just and honourable war is the true exercise. A civil war, indeed, is like the heat of fever, but a foreign war is like the heat of exercise and serves to keep the body in health." Here body politic is compared to a natural body, and war is compared to exercise. But natural body is a living organism, while body politic is not so. Here the essential difference between them is ignored.

(2) *Confusion of essential with inessential qualities.*

False analogy arises when essential properties are confused with inessential ones. The argument put by Plato into the mouth of Socrates in the *Republic*, "that if justice consists in keeping property safe, the just man must be a kind of thief; for the same kind of skill which enables a man to defend property, will also enable him to steal it" is an example of false analogy of this kind. Justice is not a kind of skill, but a kind of activity. It is a habit of action, and not a capacity or skill.

(3) *The use of metaphorical language.*

False analogy arises from the use of metaphorical language. By using metaphorical language we assume the existence of a similarity where none exists. The use of similes and metaphors gives rise to false analogy. Thus, the metropolis is compared to the heart, the king to the

father, the Prime Minister to the captain of a ship, etc. "The metropolis of a country is similar in many respects to the heart of an animal body ; therefore the increased size of a metropolis is a disease." "As the father is obeyed by children, so the subjects should obey the king." "The captain of a ship is obeyed by everybody on board the ship. Therefore, the Prime Minister, who is the captain of the ship of the State, ought to be obeyed by every subject of the State." These arguments are instances of false analogy due to *similarity in relations.* False analogy arises from the confusion of *figurative resemblance* with real resemblance. "As plants grow upwards towards the sun, it is consistent with human nature to follow the light of reason." "As too much rain reduces the crop, too many sons bring reproach." These are instances of false analogy.

QUESTIONS

1. Explain the nature of Inference from Analogy. How does it differ from Induction? In what sense is it described as Incomplete Induction?

2. Distinguish between Analogy and Induction. Explain the functions of Analogy in Induction. Can Induction be regarded as analogical argument?

3. How would you distinguish between a sound and an unsound Analogy? Give an example of a good, and an example of a bad, analogical reasoning.

4. Distinguish Analogy from Induction by Simple Enumeration. Compare the cogency of the two processes.

5. Compare Analogy with Induction and Deduction.

6. How would you estimate the value of an analogical argument?

7. What are the conditions of a good argument from Analogy ?

8. State and criticise Mill's method of testing the value of an analogical argument.

9. "The value of an analogical argument depends not on the *quantity* of similarity but on its *quality*." Elucidate the statement.

10. "If after much observation of *B*, we find that it agrees with *A* in nine out of ten of its known properties, we may conclude with a probability of nine to one that it will possess any given derivative property of *A*." (*Mill*).

"The force of an argument from Analogy depends upon the character of the identity, and not upon the apparent amount of similarity." (*Welton*).

Discuss the comparative validity of the above statements with suitable examples.

11. The value of an analogical inference depends on the *degree* as well as on the *kind* of resemblance. Show by examples how one kind of resemblance may be more important than another as the ground of inference.

12. Show how the value of an analogy may be represented by a fraction having as its numerator the resemblances between the two things compared; and as its denominator the differences between them *plus* the number of qualities of which we are ignorant.

13. What should be the character of resemblance upon which analogy is based ?

14. How is the strength of an analogical argument measured?

15. How far may Analogy be regarded as true Induction ?

16. What cautions should be observed in analogical reasoning ?

17. It has been said that every inductive argument is really analogical. Explain and discuss this.

18. What are the various senses in which the word Analogy has been used ?

19. Test the following arguments:—

(1) All religions lead to God. for do not all roads lead to Rome, and all rivers fall into the sea ?

(2) "The capital (London) has become an overgrown monster; which like a dropsical head, will in time leave the body and extremities without nourishment and support—what wonder that our villages are depopulated, and our farms are in want of day labourers." (*Smollet*).

(3) A civilised country depends on the circulation of its money as much as a living animal depends on the circulation of its blood. It is, therefore, the duty of a civilised Government promptly to pump back again to the extremities of the land the congested wealth in the cities.

(4) A community consists of individuals, and an individual consists of cells. Both of them are complex structures. The individual grows and so does the community. The community thrives when members co-operate with one another. and the health of the individual is dependent on the organs working in harmony. There being such close resemblance between the individual and the community, it is obvious that the community, like the individual, is mortal.

(5) I am like my father. My father died young. Therefore, I shall also die young.

(6) Joseph's son must be very intelligent, for he behaves exactly like one of my own students, who I know is an exceptionally bright boy.

(7) Life is but light, and no wonder that a man should be cut off in the prime of life ; a light burning brightly is very often put out by a puff of wind.

(8) Is not dirt washed away by a current of water ? Yes. Then is it impossible that all the sins of omission and commission may be washed away by the holy water of the Ganges when one

dips into it? No. Thus, it matters little how one acts or thinks so long as he periodically bathes in the Ganges.

[Sin (*moral dirt*) is compared to dirt (*physical dirt*). There is absolutely no similarity between them. There is a *figurative resemblance.*]

(9) These splints cured John's broken leg (physical); therefore they will cure my broken heart (mental).

(10) The inner world of mind attains the light of knowledge through seven *organs of sense;* therefore some mediaeval astronomers said, there must be seven *planetary bodies* to illuminate the outer world of nature.

(11) A house without tenants, a city without inhabitants present to our minds the same idea as a planet without life, a universe without inhabitants.

(12) The people of India live as fishes do in the sea, the great ones eat up the little. For, first the farmer robs the peasant, the money-lender robs the farmer, the greater robs the lesser, and the king robs all. (This is a mere simile).

(13) *Steel*, when brought to white heat in the fire, must be plunged into cold water in order to obtain the requisite temperature. Similarly the *human body* after steam bath, on being cooled down, becomes strong and hardy.

(14) I am a Jew. Hath not a Jew eyes? Hath not a Jew hands, organs, dimensions, senses, affections, passions, fed with the same food, hurt with the same weapons, subject to the same diseases, healed by the same means, as a Christian is? If you prick us, do we not bleed? If you tickle us, do we not laugh? And if you wrong us, shall we not revenge? If we are like you in the rest, we will resemble you in that.

[This is an argument from *analogy*. A Jew resembles a Christian in *physical* and *mental* qualities. There is an *essential similarity* between them. Therefore if a Christian has a right to revenge, a Jew also has the same right as they are essentially alike. This is a *sound analogy*].

(15) Galileo saw with his telescope that the planet Jupiter is the centre about which several satellites revolve receiving light and warmth from it; and appealed to this fact as an argument to prove that the Sun is a centre about which the Earth and other planets revolve as satellites. What was the logical character of Galileo's reasoning here and what, in your opinion, was its logical value?

(16) Riches are a power like that of electricity. To get work of electricity, it must be allowed to flow from a place of high to a place of low potential. Similarly the force of the guinea you have in your pocket depends wholly on the default of a guinea in your neighbour's pocket.

(17) Among men, as in trade, the bad coin drives out the good. The career of politics tends inevitably to become a monopoly of the doubtful, the unfit, and the dishonest.

(18) Medicine often fails of its effect, but poison never; likewise, in the body politic, patience is often disappointed of her hope and wisdom of her aim, but never is folly fruitless of mischief, nor does vice conclude except in calamity.

CHAPTER IX

THEORY OF PROBABILITY
ELIMINATION OF CHANCE

1. The Place of Probability in Inductive investigation.

We have seen that Analogy is a kind of Incomplete Induction. It is an inference from particulars to particulars yielding probable conclusions. It compares two instances and argues from their known resemblance to further resemblance. It yields a probable conclusion—the probability varying in degrees. Probability also is a kind of Incomplete Induction. It is an inference from particulars to particulars yielding probable conclusions. It compares many instances of the concurrence of phenomena and arrives at approximate generalisations (*e. g.*, 'Most A's are *x*') by eliminating chance coincidence. Though the probability of an analogical argument is sometimes measured by a fraction, it is not so exact as that of approximate generalisations reached by the elimination of chance. There are rules for calculating the exact degree of probability by eliminating chance. Analogy and Probability both fail to yield general conclusions. So both are sometimes called Incomplete Inductions.

We have seen how the Experimental Methods are variously affected by the difficulties arising from the

Plurality of Causes and the Intermixture of Effects; how the Method of Residues can partly cope with Homogeneous Intermixture of Effects, and how the Deductive Method in its two forms can completely cope with it. We have also seen how the Experimental Methods are liable to be frustrated by the Plurality of Causes. The Method of Agreement is particularly frustrated by it. It cannot conclusively prove whether A or B or C is the cause of x. In cases where exact results cannot be attained, we may employ the *Theory of Probability* and determine the causal connection. If we find that A and x happen together more frequently than B and x, or C and x, we conclude that the probability of A being the cause of x is greater than that of B or C being its cause. The greater frequency of the concurrence of A and x shows that there is probably some *causal connection* between them, and it is not a pure chance coincidence. The Theory of Probability formulates certain rules for the elimination of chance and helps the discovery of causes. Bain says, "An important resource in eliminating the irrelevant antecedents or accompaniments of an effect is obtained through the calculation of Chance or Probability."[1]

2. Chance.

Ordinary people believe that there is a blind irrational power which disturbs the regularity of nature. It suspends the Law of Causality at times. It is responsible for causeless events. There are certain phenomena of

1 *Logic: Induction*, p. 84.

nature which have no assignable causes. A lightning strikes a man dead. A storm blows a house away. A flood sweeps crops away in a particular region. A grain of sand lies in a particular place on the beach. A leaf falls to the ground on a particular spot. Ordinary people believe that these events are due to chance; they are accidental; they have no causes. This popular belief is irrational. The Law of Causality governs the whole of nature. All phenomena of nature are determined by their causes. There is not a single event without a cause. There is no scope for a causeless event in the Unity of Nature. There is no room for chance or accident in nature in the sense of a causeless event. "There is no doubt in lightning as to the point it shall strike; in the greatest storm there is nothing capricious; not a grain of sand lies upon the beach but infinite knowledge would account for its lying there; and the course of every falling leaf is guided by the same principles of mechanics as rule the motions of the heavenly bodies."[1] When ordinary people assert that an event happens by chance, they simply confess their ignorance of the causes that are operative. Thus, chance is not the denial of causality, but the ignorance of causality.

But sometimes two or more phenomena concur or occur together at a certain point of time and space, which are not known to be causally connected. When I go out for a walk in the morning, I happen to meet a gentleman now and then. There is no causal connection between the two events; yet they occur together

1 Jevons: *The Principles of Science*, Vol. I, p. 225.

sometimes. This is called "chance coincidence." The concurrence of two or more events at a particular point of time, not causally connected with each other, is said to be due to chance. *Chance does not apply to single events which are not uncaused, but to a concurrence of two or more events which have no obvious causal connections.* Chance applies to *coincidence* of events either in the form of *sequence* or *co-existence*. "A chance coincidence is one where there is no implied connexion of cause and effect."[1] (*Bain*).

"It is incorrect to say that any phenomenon is produced by chance; but we may say that two or more phenomena are *conjoined by chance*, that they co-exist or succeed one another only by chance: meaning that they are in no way related through causation; that they are neither cause and effect, nor effects of the same cause, nor effects of causes between which there subsists any law of co-existence, nor even effects of the same collocation of primeval causes."[2] (*Mill*). **Chance is taken by Mill in the sense of "coincidence from which we have no ground to infer uniformity"[2] or causal connection.** Chance is casual coincidence of phenomena which are determined by their causes and laws, though their *concurrence* cannot be traced to any cause, law, or definite collocation of circumstances. Mill says: "Facts casually conjoined are separately the effects of causes, and therefore of laws; but of different causes, and causes not connected by any law."[2]

1 *Logic: Induction*, p. 85.

2 *Logic*, XVII, §2.

3. Probability.

Mill says: "The probability of an event is not a quality of the event itself, but a mere name for the degree of ground which we have for expecting it. Every event is in itself certain, not probable: if we knew all, we should either know positively that it will happen, or positively that it will not. But its probability to us, means the degree of expectation of its occurrence, which we are warranted in entertaining by our present evidence."[1] The estimation of such *rational expectation* based on experience is the province of the Theory of Probability.

Bain says: "Probability expresses a *state of the mind*, and also a *situation among objective facts*. As a state of the mind, it is a grade or variety of Belief. The highest degree of belief is called Certainty; the inferior degrees are degrees of Probability. As a situation of objective facts, it points to our experience of the recurrence of events with more or less uniformity What happens always, under certain circumstances,—as the rise of the sun, is called certain. What happens, not always, but sometimes,—as that the sun rises in a cloudless sky,—is not certain. Neither the fact nor the failure of the fact is certain. To this middle situation, is applied the term Probability."[2] Probability is both subjective and objective. It relates to doubt or uncertainty due to our estimate of facts. It is a degree of belief based on the experience of facts.

1 *Logic*, XVIII, § 1.

2 *Logic*, *Induction*, p. 90.

Probability is less than certainty and more than impossibility. What is self-contradictory is impossible. What happens but rarely is possible. What happens frequently is probable. What happens always is certain. Probability is a middle situation between impossibility and certainty. Popularly, an event is said to be 'probable', when it is more likely than not to happen. "But, scientifically, an event is probable if our expectation of its occurrence is less than certainty, as long as the event is not impossible."[1] (*Carveth Read*). Probability is less than certainty and greater than impossibility. By certainty we mean rational certainty humanly attainable. We do not take it in the sense of absolute certainty.

Probability is sometimes represented by a **fraction.** **Laplace** states that Probability may be represented by "a fraction, having for its *numerator* the number of cases *favourable* to the event, and for its *denominator* the number of all the cases which are *possible*." **Carveth Read** says: "Taking 1 for certainty, and 0 for impossibility, probability may be $\frac{999}{1000}$, or $\frac{1}{1000}$, or (generally) $\frac{1}{m}$. The denominator represents the number of times that an event happens, and the numerator the number of times that it coincides with another event"[1] Since there are only two sides of a coin,—head and tail,—the probability of head turning up in any throw is $\frac{1}{2}$. Similarly, there are four aces in a pack of fifty-two cards. Therefore, the probability of getting an ace in any draw is $\frac{4}{52}=\frac{1}{13}$. Likewise, in a game of dice, the probability of ace turning up is expressed by a fraction, having for its denominator the

1 *Logic*, p. 312.

number of throws, and for its numerator the number of times that ace is thrown. In a sufficient number of throws, the probability of ace turning up would approximate to $\frac{1}{6}$.

Probability is sometimes represented as a **proportion.** If the fraction expressing the probability of ace turning up is $\frac{1}{6}$, the proportion of cases in which it happens is 1 to 5 ; or, the chances are 5 to 1 against it, or, the chances in favour of its happening are 1 : 5, and the chances against its happening are 5 : 1. The ratio of the number of cases favourable to the event to the number of possible cases, is the measure of probability.

4. Chance and Probability.

Popularly, chance means accident or denial of causality. Scientifically, chance means casual coincidence of events which are not causally connected. But if the concurrence of events is more frequent than expected, we suspect a causal connection. We can calculate the probability of their concurrence by eliminating chance or casual coincidence. We get data for calculating probability by eliminating chance.

5. Distinction between Probability and Induction.

Probability is rational expectation of the concurrence of events based on experience. It is subjective as well as objective. It is a subjective conviction based on the experience of an objective situation. It arrives at approximate generalisations on the ground of experience of frequent concurrence of events. Induction, on the

other hand, arrives at universal propositions on the ground of the causal connection established between the ground of inference and the inferred property. Both Probability and Induction are based on observation of facts. But the former arrives at approximate generalisations which are particular propositions, while the latter arrives at universal propositions or generalisations without any exception. The former calculates the degree of probability of the concurrence of events by eliminating chance, but cannot conclusively prove a causal connection. But the latter proves a causal connection between two phenomena by means of the Experimental Methods.

6. Relation of Probability to Induction.

There is a difference of opinion as to the relation between probability and induction. **Jevons holds that Induction is based on Probability.** It is based on the assumption that Nature is uniform in her behaviour and the same cause produces the same effect under the same circumstances. But we are not absolutely certain of the uniformity of causation. Moreover, we cannot prove a causal connection with absolute certainty, because our knowledge of causes, laws, and collocations of circumstances is very imperfect. Therefore inductions yield only probable conclusions. Carveth Read states his view thus: "It has been urged that induction is itself based upon probability; that the subtlety, complexity and secrecy of nature are such, that we are never quite sure that we fully know even what we have observed; and that, as for laws, the conditions of the universe may at

any moment be completely changed ; so that all imperfect inductions including the law of causation itself, are only probable."[1]

But the view of Jevons is wrong. His view is based on an ambiguity in the word 'certainty'. He takes 'certainty' in the sense of 'absolute certainty'. Therefore he holds that inductions are probable, and the Uniformity of Nature also is probable. He says: "Inductive inference might attain to certainty, if our knowledge of the agents existing throughout the universe were complete, and if we were at the same time certain, that the same power which created the universe will allow it to proceed without arbitrary change." From the standpoint of 'absolute certainty' everything is probable including induction and its presuppositions, *viz.*, the Uniformity of Nature and the Law of Causality. But we should not take certainty in the absolute sense. By 'certainty' we mean 'rational certainty' humanly attainable. The word 'probable' does not mean 'less than absolutely certain' as Jevons wrongly thinks. It means 'less than certain according to *our* standard of certainty', that is, in comparison with the Law of Causality which is practically certain. From this standpoint of human or rational certainty, induction is certain. The Law of Causation is certain, and Induction based upon the establishment of a causal connection is certain.[1]

Mill, on the other hand, holds that Probability is based upon Induction. Probability is based on the observation of the comparative frequency of the concur-

1 *Logic*. p..315.

rence of events. It seeks to distinguish between casual coincidence and causal coincidence on the ground of experience. Probability, therefore, depends upon induction or experience and causation. **Mill** says : "Calculation of chances is grounded on an induction. and to render the calculation legitimate, the induction must be a valid one. It is not less an induction, though it does not prove that the event occurs in all cases of a given description, but only that out of a given number of such cases, it occurs in about so many."[1] Probability is based upon induction, because it is based upon observation of comparative frequency of concurrent events. **Bain** says, "If, in the run of many years, it appears that there have been, in some one place four dry days for three wet, then it is a matter of inductive certainty, that in the future that proportion will hold good."[2]

Carveth Read also holds the same view. He says. **"Induction, humanly speaking, does not rest on probability ; but the probability of concrete events rests on induction and, therefore, on causation.** The inductive evidence underlying an estimate of probability may be of three kinds : (*a*) direct statistics of the events in question ; as when we find that, at the age of 20, the average expectation of life is 39–40 years. This is an empirical law, and, if we do not know the causes of any event, we must be content with an empirical law. But (*b*) if we do know the causes of an event, and the causes which may prevent its happening, and can estimate

1 *Logic*, XVIII, § 3.

2 *Logic, Induction*, p. 91.

the comparative frequency of their occurring, we may deduce the probability that the effect (*i. e.* the event in question) will occur. Or (*c*) we may combine these two methods, verifying each by means of the other. Now either the method (*b*) or (*a fortiori*) the method (*c*) (both depending on *causation*) is more trustworthy than the method (*a*) by itself."

"But, further, a merely empirical statistical law will only be true as long as the causes influencing the event remain the same. A die may be found to turn ace once in six throws, on the average, in close accordance with mathematical theory; but if we load it on that facet the results will be very different. **Hence probability depends upon causation, not causation upon probability.**"[1] Thus Carveth Read holds with Mill that Probability is based upon Induction.

7. Grounds of Probability.

There is a difference of opinion as to the grounds of Probability. Some logicians (*e. g.*, **Jevons**) hold that the ground of Probability is *subjective*; Probability depends upon the *quantity of our belief* in the occurrence of an event, or in its concurrence with some other event. Others (*e. g.*, **Carveth Read**) hold that the ground of Probability is *objective*: Probability depends upon *experience* of comparative frequency of the concurrence of events.

1 *Logic*, p. 317.

Carveth Read puts forward the following objections against the view that probability depends upon the quantity of belief :—

(1) *Firstly, the subjective state of belief cannot be satisfactorily measured.* Belief, as a state of the mind, has no definite numerical value. It cannot be expressed by a fraction, as $\frac{1}{10}$ or $\frac{1}{100}$. "Let anybody mix a number of letters in a bag, knowing nothing of them except that one of them is X, and then draw them one by one, endeavouring each time to estimate the value of his belief that the next will be X ; can he say that his belief in the drawing of X next time regularly increases as the number of letters left decreases?"[1] Where statistical evidence is available, no one thinks of calculating probability by the quantity of his belief.

(2) *Secondly, the subjective state of belief does not uniformly correspond with the state of the facts.* "Belief is subject to hope and fear, temperament, passion, and prejudice, and not merely to rational considerations...... The experience of two men may be practically equal, whilst their beliefs upon any question greatly differ."[2] A credulous person is ready to believe on insufficient evidence. But a person of a sceptical turn of mind is slow to believe even on adequate evidence. Hence probability cannot depend upon belief, but upon experience of facts.

(3) *Thirdly, "if Probability is to be connected with Inductive Logic, it must rest upon the same ground, namely, observation."*[3] Psychology is concerned with belief as a

1 *Ibid*, p. 313. 2 *Ibid*, pp. 313—14. 3 *Ibid*, p. 314.

state of the mind. Inductive Logic is concerned with Probability based upon experience of facts. Induction is not content with mere beliefs or opinions, but aims at testing, verifying, and correcting them by experience of facts. *Both Induction and Probability are based upon experience or observation of facts.*

Hence Probability as treated in Inductive Logic is both subjective and objective. It is a state of the mind and, therefore, *subjective.* It is grounded on experience of a situation and, therefore, *objective.* Inductive Logic is concerned with Probability not as a purely subjective state of mind, which is not grounded upon objective facts. Thus Probability has the same object and the same basis as Induction. "The ground of probability is experience and, wherever possible, statistics; which are a kind of induction." (*Carveth Read*). *Therefore, Probability may be said to be based upon Induction.*

8. Elimination of Chance.

Chance is a casual coincidence of events which are not causally connected. But if two events concur frequently, we suspect a causal connection. If they concur rarely, we do not suspect any causal connection. Thus we distinguish between *casual* coincidence and *causal* coincidence, and eliminate the former in order to determine the latter. The Elimination of Chance is a method by which we show that coincidence or concurrence of two events is not *casual* but *causal*, because of its *frequency*, which cannot otherwise be accounted for. **Bain** formulates the following rule for the elimination of chance:—

"*Consider the positive frequency of the phenomena themselves, and how great frequency of coincidence must follow from that, supposing there is neither connection nor repugnance. If there be a greater frequency, there is connexion; if a less, repugnance.*"[1] (*Bain*).

By 'positive frequency' Bain means the number of times each of the concurring events would occur naturally by itself. "If we find from observation (sufficiently extended to generalize the facts) that A exists in one instance out of every two, and that B exists in one instance out of every three ; then, if A and B are wholly indifferent to each other—neither connected nor repugnant—the instances of A and B happening together will be one out of every six, on a sufficient average. If, really, the two co-exist oftener, there is connexion ; if seldomer, repugnance."[1] Suppose we are considering whether there is any causal connection between drunkenness and criminality. We should consider the positive frequency of each of these phenomena. Suppose drunkenness occurs in one instance out of every ten, and criminality occurs in one instance out of every twenty ; if they are not causally connected, they will occur together once in every two hundred instances. But, if we find, as a matter of fact, that they occur together more frequently, we suspect a causal connection between them ; if, on the other hand, we find that they occur together less frequently we suspect a repugnance between them. Let us consider the rules for calculation of chances and estimation of probability.

1 *Logic : Induction*, p. 86.

9. Rules for Calculation of Chances or Estimation of Probability.

The following are the principal rules for calculation of chances:—

(1) Rule for Determining the Occurrence of Single Events. *The probability of the occurrence of a single event is expressed by a fraction whose numerator is the number of favourable chances and whose denominator is the total number of possibilities.*

For example, in throwing a coin once the probability of getting heads is $\frac{1}{2}$, because only two alternatives are possible—heads and tails. In one throw of a die, the probability of the ace turning up is $\frac{1}{6}$. The total number of times a die can turn up in six throws is six. So the number 6 constitutes the denominator. The turning up of the ace is one of the six possibilities. Therefore, the probability of the ace turning up is once in six throws. So the number 1 constitutes the numerator. The probability of the ace turning up in one throw is $\frac{1}{6}$.

(2) Rule for Determining the Concurrence of Two Independent Events. *The probability of the concurrence of two independent events is the product of the separate probabilities.* If two events are independent, having neither connection nor repugnance, the probability of their concurrence is measured by multiplying the separate probabilities of the occurrence of each event.

If A occurs once in four times, its probability is $\frac{1}{4}$, or 1 for and 3 against; if B occurs once in six times, its probability is $\frac{1}{6}$, or 1 for and 5 against. The probability

of the concurrence of A and B is measured by the product of the two fractions $\frac{1}{4}$ and $\frac{1}{6}$ *i. e.* $\frac{1}{24}$, 1 for and 23 against. If, in walking down a street I meet A once in four times, and B once in five times, I expect to meet by chance both A and B once in twenty times. The probability of my meeting A is $\frac{1}{4}$; the probability of my meeting B is $\frac{1}{5}$; hence the probability of my meeting both A and B is $\frac{1}{4} \times \frac{1}{5} = \frac{1}{20}$. Similarly, if 2 persons out of every 9 are intelligent, and 2 persons out of every 7 are diligent, the probability of a person being both intelligent and diligent is $\frac{2}{9} \times \frac{2}{7} = \frac{4}{63}$. In other words, out of every 63 persons, 4 persons are likely to be both intelligent and diligent.

(2) **The Rule for Estimating the Deterioration of Testimony.** *When testimony passes from one person to another, its value decreases; the value of testimony in such a case is measured by the product of the fractions expressing the separate probabilities.*

The first rule is also applied to calculate the probability of *dependent* events. It is applicable to *hearsay evidence.* If one witness A speaks truth five times in seven, his veracity is measured by the fraction $\frac{5}{7}$; if another witness B speaks truth nine times in ten, his veracity is measured by the fraction $\frac{9}{10}$. If B reports what he has heard from A, his testimony is weakened by transmission to $\frac{5}{7} \times \frac{9}{10} = \frac{45}{70} = \frac{9}{14}$. Of facts attested by B, heard from A, 9 will be true and 5 false. If there are four witnesses,—testimony passing from one to another,—and each speaks truth once in three times, the trustworthiness of the last witness will be $\frac{1}{3} \times \frac{1}{3} \times \frac{1}{3} \times \frac{1}{3} = \frac{1}{81}$. Thus, the

deterioration of testimony passing from one person to another can be measured by the product of the fractions representing the separate probabilities. The value of tradition is very little, because here testimony passes from one generation to another and is weakened, to a very great extent, by transmission.

(3) **Rule for Determining the Occurrence of Either of Two Inconsistent Events.** *The probability of the occurrence of either of two events that cannot concur is the sum of the separate probabilities.*

If two events are mutually exclusive, the probability of getting one or the other is the sum of their separate probabilities. For example, a die cannot turn up ace and six; but the probability of the occurrence of each is $\frac{1}{6}$; therefore the probability of the occurrence of either one or the other is $\frac{1}{6}+\frac{1}{6}=\frac{1}{3}$. Death cannot be brought about by cholera and plague both on a particular occasion; if 1 in 2000 dies of cholera and 3 in 4000 die of plague, the probability of dying of cholera or dying of plague is $\frac{1}{2000}+\frac{3}{4000}=\frac{5}{4000}=\frac{1}{800}$. The same mango cannot be both sweet and sour. If 3 mangoes are sweet out of every 10 mangoes, and 4 mangoes are sour out of every 7 mangoes, then 61 mangoes are either sweet or sour out of every 70 mangoes. The probability of mangoes being either sweet or sour is measured by adding together the two fractions representing the separate probabilities, *viz.*, $\frac{3}{10}+\frac{4}{7}=\frac{61}{70}$.

(4) **Rule for determining the Cogency of Cumulative Testimony.** *The probability of trusworthi-*

ness of cumulative evidence is measured by subtracting the product of the separate improbabilities from unity. In cumulative testimony independent events support one another.

If there are two *independent* witnesses A and B, and A speaks truth once in five times, and B speaks truth once in four times, then the reliability of A is $\frac{1}{5}$, and the reliability of B is $\frac{1}{4}$. Therefore, the unreliability of A is $\frac{4}{5}$, and the unreliability of B is $\frac{3}{4}$. The combined unreliability of A and B, therefore, would be $\frac{4}{5} \times \frac{3}{4} = \frac{3}{5}$. The reliability of their cumulative testimony, therefore, would be $1 - \frac{3}{5} = \frac{2}{5}$. If there are three independent witnesses, and the probabilities of their speaking truth be represented by $\frac{1}{4}$, $\frac{2}{3}$, and $\frac{3}{4}$, then their separate improbabilities are represented by $\frac{3}{4}$, $\frac{1}{3}$, and $\frac{1}{4}$ respectively. The combined improbability of their evidence is measured by their product, *viz.*, $\frac{3}{4} \times \frac{1}{3} \times \frac{1}{4} = \frac{1}{16}$. Therefore, the probability of the fact happening attested by such *independent* witnesses is $1 - \frac{1}{16} = \frac{15}{16}$. The rule for determining the probability of circumstantial evidence also is the same as that for estimating the value of cumulative evidence.

10. Experimental Verification of Probability.

Rules for the estimation of Probability express mathematical chances. But experience of a limited number of instances sometimes shows that the mathematical chances do not exactly correspond with the actual chances. But the more the number of trials is increased, the result is found to approximate more nearly to the mathematical chances. In twenty throws of a penny the chances of throwing heads are not found to express the

mathematical chances, *viz.*, $\frac{1}{2}$. But the discrepancy will tend to disappear as the number of throws is increased. Buffon tossed a coin 4040 times, in which 1992 came tails and 2048 came heads. De Morgan tossed a coin 4092 times, in which 2044 came tails and 2048 came heads. Jevons took ten coins, tossed them, and noted each time the number of heads. Out of a total of 20,480 throws, he got a result of 10,353 heads. Hence, the actual chances pretty closely correspond with mathematical chances.

11. The Application of the Theory of Probability to the Determination of Causes.

We can apply the Theory of Probability to the determination of causes, where effects may be produced by any one of several causes. **Mill** says: "Given an effect to be accounted for, and there being several causes which might have produced it, but of the presence of which in the particular case nothing is known; the probability that the effect was produced by any one of these causes *is as the antecedent probability of the cause, multiplied by the probability that the cause, if it existed, would have produced the given effect.*"

"Let M be the effect, and A, B, two causes, by either of which it might have been produced. To find the probability that it was produced by the one and not by the other, ascertain which of the two is most likely to have existed, and which of them, if it did exist, was most likely to produce the effect M: the probability sought is a compound of these two probabilities."[1]

1 *Logic*, XVIII, § 5.

Suppose the probabilities of A's and B's existence at the time when M is produced are respectively $\frac{3}{4}$ and $\frac{5}{8}$. Suppose that if A exists at the time, the probability of its producing M is $\frac{1}{2}$, and that if B exists, the probability of its producing M is $\frac{1}{5}$. Then the total probability of A's producing M is $\frac{3}{4} \times \frac{1}{2} = \frac{3}{8}$; and the total probability of B's producing M is $\frac{5}{8} \times \frac{1}{5} = \frac{1}{8}$. Therefore, the probability of A producing M is greater than that of B producing it ; the probability is in favour of A in the proportion of three to one. In other words, A is more likely to be the cause of M than B.

12. Statistics.

Statistical methods depend upon counting or enumeration of instances. They aim at making the process of counting exact and precise. Statistics give us a clue to causal connections among most complex phenomena. At least, they supply us with empirical laws which guide us in our practical life. The statistical method is employed by modern sciences to discover the causes of most complex phenomena and make our knowledge exact and precise.

Creighton says : "In the first place, the class of facts to which statistics are applied has two main characteristics: the subject dealt with is always complex, and capable of division into a number of individual parts or units; and secondly, it is also of such a nature that the underlying law or principle of the phenomena to be investigated cannot be directly discovered. Thus we employ statistics to determine the death-rate of any country or community, or the ratio between the number of male and of female

births."[1] In cases like these, where we are as yet unable to determine the general laws at work, we adopt the statistical method.

The statistical method has three main advantages. (1) Firstly, statistical enumeration contributes directly towards a clear and comprehensive grasp of the facts. It renders observation exact and trustworthy, and sums up the results of observation in a convenient and intelligible form. (2) Secondly, statistical enumeration of a large number of instances in the past gives us the *average*, which enables us to form probable judgments as to what will happen in the future in cases where causal laws are unknown. Insurance companies calculate the averages of deaths at particular ages and determine the premia in proportion to the risk. (3) Thirdly, statistics often reveal quantitative correspondences between two groups of phenomena, and thus suggest that some causal connection exists between them. For example, it is found that the number of births in any given country tends to vary in proportion to the abundance or scarcity of food. This suggests a causal connection between the two phenomena. In general, causal laws are suggested by corresponding variations in two sets of facts. If the death-rate shows a constant ratio to the population, it does not suggest any causal connection. But if the ratio of deaths increases or decreases considerably, we look for its cause in the variation from the normal in some other group of phenomena, *e. g.*, the presence or absence of epidemics. We suspect a causal connection between two phenomena,

1 *An Introductory Logic*, p. 261.

when we find a quantitative proportion between their variations. Thus, the statistical method makes our observation exact and precise, gives us an idea of the average which may apply to the future, and suggests causal connection.[1]

"Statistical enumeration is frequently employed to determine the *average* of a large number of instances of a particular kind. This is obtained by dividing the sum of the given numbers by the number of individuals of which account is taken. In this way a *general average* is reached which does not necessarily correspond exactly with the character of any individual of the group. From the mean or average of a number of individuals, or set of instances, however, we can infer nothing regarding the character of any particular individual, or of any particular instance."[2] When we say that the average height of Frenchmen is five feet six inches, and the average height of Englishmen is five feet ten inches, we can easily compare the two groups of persons. The average does not apply to individual Englishmen or Frenchmen.

QUESTIONS

1. What do you mean by Probability? Discuss the relation of Probability to Induction.

2. Explain and illustrate the rules for the calculation of Probabilities.

3. Distinguish between Probability and Induction. What are the logical grounds of Probability?

---

1 *Ibid*, pp. 262—64.

2 *Ibid*, p. 268.

4. Distinguish between Chance and Probability, and show how the method of Probability enables us to eliminate chance.

5. What is meant by Chance? How is it eliminated?

6. Explain and discuss the doctrine that Induction is based upon the Theory of Probability.

7. Discuss the relation between casual coincidence and causal coincidence.

8. Explain the application of the Theory of Probability to the inductive determination of causes.

9. If the probability of A's occurrence by itself be 1 : 5, and that of B's occurrence by itself is 1 : 9, then what would be the probability of their concurrence?

10. How may statistics be used to prove or disprove a law of causal connection? Illustrate your answer.

CHAPTER X

EXPLANATION

1. The Nature of Explanation.

Scientific explanation consists in finding out the cause of an event and the law of its operation. It consists in deducing a law from a higher law. **Jevons says: 'Scientific explanation consists in harmonizing fact with fact, or fact with law, or law with law, so that we may see them both to be cases of one uniform law of causation."**[1] If we hear of an earthquake in a place, and subsequently hear of a volcanic eruption in the neighbourhood, we say that the earthquake is explained. When we find that many trees are uprooted in a place, and subsequently hear that a terrible storm raged there, we say that the fact is explained. These are considered explanations of *facts* by *facts*. When we find bodies falling to the ground, we explain the fall by the Law of Gravitation. When we find that glass cracks when it is heated, we explain it by the general law that heat expands solid bodies. These are considered explanations of *facts* by *laws*. We explain the laws of movements of planets and the laws of ebb and tide by deducing them from the Law of Gravitation. These are considered explanations of *laws* by *laws*.

Nature is a system of inter-connected events. A fact is explained when it is assigned a place in the system. A law is

---

1 *Elementary Lessons in Logic*, p. 264.

explained when it is shown to be a particular case of a higher law. A fact or a law is a necessary element in the Unity of Nature. In either case we seek to connect facts with known facts or laws, and laws with known laws. Scientific explanation consists in *assimilation.* We explain a fact by finding out similarities between it and other facts. Franklin explained the phenomenon of lightning by assimilating it to electricity. We explain a law by finding out similarities beween it and other laws. Newton explained Kepler's laws of planetary motion by showing their similarity with the Law of Gravitation.

Carveth Read says: "Scientific Explanation consists in discovering, deducing, and assimilating the laws of phenomena." Facts are explained when we *discover* their causes and laws. Laws are explained when we *deduce* them from higher laws. Facts and laws are explained when we *assimilate* them to other known facts and laws. Explanation consists in finding out the resemblances between the phenomenon under investigation and other phenomena. "The basis of all scientific explanation consists in assimilating a fact to some other fact or facts. Our only progress from the obscure to the plain, from the mysterious to the intelligible, is to find out *resemblances* among facts, to make different phenomena, as it were, fraternize. We can explain a motion by comparing it with some other motion, a pleasure by reference to some other pleasure. Explanation steadily proceeds side by side with assimilation, generalization. Combustion was explained by oxidation; oxidation is explained by the higher generality—chemical combination; chemical

combination is swallowed up in the Conservation of Energy."[1] (*Bain*).

The goal of scientific explanation is to satisfy our intellectual curiosity and reduce a chaos of facts to a unity. Its aim is also to master the forces of nature and harness them to our service. We seek to be the masters of the environment in which we live. We do not want to be its blind tools to be moulded and fashioned by it.

2. Popular Explanation and Scientific Explanation.

Scientific explanation differs from popular explanation, though both of them involve assimilation.

Firstly, popular explanation rests content with establishing *superficial resemblances*, while scientific explanation tries to find out *fundamental similarities.* Ordinary people look upon bats as birds because they can fly. But the scientist regards them as mammals akin to men. Bats suck the breasts and give birth to young ones. They do not lay eggs.

Secondly, popular explanation connects a *fact* with other *facts known* already. In the popular view, facts are explained when they are brought into relation with other facts already known. But in scientific explanation we try to find out their *causes* and *laws.* Ordinary people explain the fall of an apple to the ground by pointing out that other bodies also fall to the ground. But the scientist explains it by the Law of Gravitation. Scientific-

1 *Logic : Induction*, pp. 116—17.

explanation is more concerned with the explanation of *laws* than of facts.

Thirdly, popular explanation is guided by *practical interest;* it explains those facts which have a bearing on our practical life. Scientific explanation, on the other hand, is mainly guided by *theoretical interest.* If your house catches fire and is reduced to ashes, you will try to find out the cause of this fire. But Chemistry tells you what is the cause of combustion in general.

Fourthly, popular explanation sometimes accounts for facts by *supernatural* agencies, while scientific explanation seeks to explain facts by *natural* causes and laws. Ordinary people explain a lunar eclipse by a dragon's devouring the moon, but science explains it by the passage of the moon through the shadow of the earth.

Lastly, popular explanation depends upon the knowledge of an individual, while scientific explanation depends upon the progress of knowledge as a whole at any particular time. The plain man attributes a chill on the liver to the cold winds that have blown. He does not go beyond this. But a doctor is not satisfied with this explanation. He seeks for reasons why the cold should affect the liver at all. He finds them in his general knowledge of the functions of liver in relation to the rest of the body and in the effect of cold upon them. His explanation takes a wider view and depends upon scientific knowledge of physiological functions.[1]

1 *An Intermediate Logic*, p. 441.

3. Forms of Scientific Explanation.

Mill enumerates three forms of scientific explanation: (1) Resolution ; (2) Concatenation or Interpolation ; and (3) Subsumption.

(1) Resolution.

A complex phenomenon is explained when it is referred to the separate laws of its causes from the combination of which it arises. We analyse a complex effect in order to find out the various causes and laws that act together to produce it. We explain Intermixture of Effects in this way.

(1) When a path of a projectile is explained by reference to the laws of gravitation, the initial force or the tendency to move in a straight line, and resistance of the air, the explanation takes the form of resolution.

(2) Thunder is followed by lightning. We may explain it by analysing it into the discharge of electricity in the air, distance of the observer from the phenomenon, and the law that light travels faster than sound.

(3) Why does a balloon rise in the air, while other bodies fall to the ground ? "The balloon is acted on, downwards by its own weight and by the pressure of the air on its upper surface ; it is acted on, upwards, by the pressure of the air on its under surface. The latter being the greater, the balloon must rise."[1] (*Venn*).

(4) The pumping of water is explained when it is analysed into pressure of the air, distribution of pressure in a liquid and motion taking the direction of least resistance.

---

1 *Empirical Logic*, pp. 504—505.

This form of explanation is employed in explaining homogeneous intermixture of effects in which the joint effect is the sum of the separate effects, and is of the same kind with them. Resolution is the same as the Deductive Method.

(2) Concatenation or Interpolation.

Explanation may assume the form of concatenation or interpolation when we discover the intermediate link or links between an antecedent and a consequent. The relation between a remote cause and a remote effect is explained by discovering the intermediate agencies between them.

(1) Lightning is followed by thunder. Lightning is electricity ; it produces heat; heat suddenly expands the air which causes sound. Therefore, lightning is followed by thunder.

(2) The sea-water is said to be the cause of rain. But it is a remote antecedent of rain. We have to supply the intermediate links such as evaporation, condensation, electric discharge, etc., to explain the connection between them.

(3) The pulling of the trigger of a musket is followed by the propulsion of a ball. We may explain the connection by discovering the intermediate links between them. "The trigger by concussion evolves heat ; the heat ignites the gun-powder ; the gun-powder is a mass adapted for rapid combustion ; the combustion evolves gases which,

being confined in a small space, have a very high expansive force ; the expansive force propels the ball."[1] (*Bain*).

(4) Chlorine is found to have a strong power of bleaching. But on closer examination it is found that it is not chlorine that has a bleaching power. But oxygen is the intermediate agent which destroys colour. Chlorine decomposes water, and combines with hydrogen, and leaves oxygen in a state of great activity and ready to destroy the colouring matter. Thus the bleaching power of chlorine is explained by discovering the intermediate agent, *viz.*, oxygen. (*Jevons*).

(3) Subsumption.

Subsumption is a form of explanation in which a law is brought under a higher law. It consists in deducing laws of less generality from more general laws. This represents the upward march of generalisation. When we have attained a number of inferior laws by assimilating particular phenomena, we gather them up into one more general law. When inferior laws are thus merged in a greater and more comprehensive law, the mind feels a satisfaction, because it reduces a multiplicity of facts into a unity. "The intellect, oppressed with the variety and multiplicity of facts. is joyfully relieved by the simplification and the unity of a great principle."[2] (*Bain*).

(1) The law of ebb and tide, the law of gravity of the earth, and the law of planetary motion are explained, when they are deduced from the higher Law of Universal Gravitation. Newton explained Kepler's laws of planetary

---

1 *Logic* : *Induction*, p. 118. 2 *Ibid*, p. 120.

motion in elliptical orbits by subsuming them under the Law of Gravitation (*i. e.*, matter attracts matter).

(2) The laws of the expansion of solids, liquids and gases by heat are explained, when they are subsumed under the general law of the expansion of bodies by heat.

(3) A number of minor laws relating to motion, heat, light, magnetism, electricity, chemical affinity, etc., are subsumed under the all-comprehending Law of Conservation of Energy. The total amount of energy existing in the universe is fixed and unalterable ; it assumes different forms, *e. g.*, heat, light, etc., which are convertible into one another, the quantity remaining the same.

(4) Many minor laws are subsumed under the Law of Relativity. "The pleasures of variety and novelty, the necessity of contrast in works of art, antithesis in rhetoric,—are minor laws generalised by the higher law."[1] (*Bain*).

4. Stages of Explanation.

Scientific explanation mainly consists in the discovery of the laws of nature. **Welton** describes three steps in the process of the establishment of laws : (1) Empirical Generalisations; (2) Establishment of Truths ; (3) Systematisation or deduction of less general laws from more general laws.

(1) Empirical Generalisations.

An empirical law is based on an observation of a large number of similar facts. It is a generalisation based upon uniform and uncontradicted experience. It is derived

1 *Logic : Induction*, p. 120.

from an Induction by Simple Enumeration. It is more of the nature of description than explanation. It comprehends a large number of facts under a descriptive law. It is itself in need of explanation. Empirical generalisations are based upon observation and experiment. When they are deduced from higher laws, they are said to be explained. Thus Galileo determined the law of falling bodies empirically ; and it remained an empirical law until Newton deduced it from the Law of Gravitation. The grounds of empirical generalisations are wholly or partially unknown. The empirical laws must not be assumed to be universally and necessarily true. They can safely be extended to adjacent cases within the limits of observation. It is an empirical generalisation that the people of cold countries use particular kinds of food and clothing. But we cannot extend it to the natives of the tropics.

Statistical laws also are empirical generalisations. They often reveal uniformities which we seek to explain by constant conditions. The number of births, deaths, suicides, etc., in proportion to the total number of the inhabitants of a country is found to be remarkably uniform. This clearly indicates the existence of constant conditions which determine the uniformity. Thus statistical uniformity points to the existence of constant material and social conditions in a country. But it would be wrong to suppose that the conditions would remain unchanged in the future. Sometimes there are deviations from statistical laws. They can be explained by some change in the social and material conditions. If we find a crime gradually increasing, suicide becoming more common, birth-rate declining

proportionately, we at once search for some variation in existing social and economic conditions which may account for the change. In this way we may find out a generalisation or law which will explain, and not merely register, the phenomenon. Thus statistics is an aid to explanation.

(2) Established Truths.

Empirical generalisations are not *necessarily* true. They are merely descriptive in nature ; they are not explanatory laws. They are explained and established as truths, when their conditions have been exactly determined. Empirical generalisations are established as universally and necessarily true, when their determining conditions have been exactly ascertained. They are established as truths, when we have accurately analysed their conditions, and distinguished between essential and inessential conditions, and taken into account all the essential conditions. Thus Kepler's empirical law was established when it was deduced by Newton from the Law of Gravitation. Kepler generalised from a large number of observations of the positions of planets that they move in elliptical orbits. Newton explained this empirical law by showing that the motions of planets are due to the combination of gravity with projectile tendency. The planets are attracted by the Sun, and they have a tendency to move in a straight line. The concurrence of these two motions results in the motions of planets. Thus *empirical laws* are established when they are deduced from higher laws under particular collocations of circumstances ; when they are thus deduced, they become *derivative laws.*

(3) Systematisation.

Systematisation is the stage at which laws are deduced from higher laws. Empirical laws are generalisations from particular facts observed. These are established as necessary truths when they are deduced from established laws. They must be brought into relations with the whole system of knowledge. Laws of less generality should be deduced from laws of greater generality. These, again, should be subsumed under primary or ultimate laws. All laws should be brought into necessary relation to one another within the system of knowledge. Systematisation is the last step in explanation. The more general is the law under which a law is subsumed, the more satisfactory is the explanation. But scientific explanation cannot go beyond primary or ultimate laws. These are said to be the limits of scientific explanation. But we believe that with the advance of knowledge they also will be found to be necessary factors in the system of knowledge. The theoretical limit of explanation is a complete knowledge of the system of the universe itself.[1] The different kinds of the Laws of Nature will be fully discussed in the next chapter.

5. Limits of Explanation.

There are certain limits to scientific explanation. Scientific explanation mainly consists in *assimilation* or finding out similarities among facts and laws. Therefore, we cannot explain those phenomena which possess remarkably peculiar qualities of their own, and hence cannot

1 *An Intermediate Logic*, pp. 444—58.

be assimilated to any other phenomena. Such phenomena beyond the scope of explanation are the following:—

(1) *Elementary experiences*, such as sensations of colour, sound, taste, smell, heat and cold, pleasure and pain, attention, etc., cannot be explained, because we cannot assimilate them to any other experiences. They are fundamental modes of consciousness. They are unique and underived. There is no similarity between colour and sound, taste and smell, pleasure and pain, etc.

(2) *The primary qualities of matter*, *e. g.*, extension, inertia, gravity, impenetrability, motion, etc., cannot be explained. They are quite distinct from one another; there is no similarity among them. They cannot be explained because they cannot be assimilated.

(3) *Individual peculiarities* of concrete objects cannot be explained because they are peculiar to particular objects, and therefore, cannot be assimilated to anything else. To try to explain them is to ignore their individuality. No one can explain why the pen in my hand is of a particular size, a particular shape, a particular colour, made of a particular stuff, and so on.

(4) *The primary or ultimate laws* cannot be subsumed under any other higher laws. They are the highest laws of generality. They cannot be deduced from any other higher laws. They are the highest generalisations of sciences. They are the ultimate limits of explanation. The Laws of Identity, Contradiction, and Excluded Middle, the Law of Gravitation, the Law of Conservation of Energy, the Law of Evolution, etc., cannot be explained.

6. Illusory or Fallacious Explanations.

Illusory explanations seem to explain facts or laws without really doing so. The main forms of illusory explanations are the following:—

(1) We sometimes explain facts by repeating them in a different language. Molier's physician explains the sleep-inducing quality of opium by reference to its soporific virtue. Similarly, we may say that we can see through glass because it is transparent.

(2) Another illusory explanation consists in regarding phenomena as simple because they are familiar. Very familiar facts seem to require no explanation. For example, the boiling and evaporation of a liquid, the lighting of a fire by contact with a flame, the succession of day and night, etc., are extremely familiar every-day experiences. Therefore, common people think that they are very simple phenomena and stand in no need of explanation.

(3) Sometimes we are not satisfied with the highest laws and try to subsume them under higher laws. The Law of Gravitation is regarded as a primary or ultimate law. But Newton could not recognise it as a primary or ultimate law. "It was inconceivable to him that matter should act upon other matter at a distance, and he therefore desired a medium of operation, whereby gravity might be assimilated to Impact. But this assimilation has hitherto been impracticable ; if so, gravity is an ultimate fact, and its own sufficing and final explanation."[1] (*Bain*). Scientific explanation cannot account for primary or ultimate laws.

---

1 *Logic* : *Induction*, p. 126.

7. Explanation and Induction.

The goal of inductive investigation is to explain particular facts by general laws of nature. Induction is an inference from particular truths to a general truth. In explanation also, particular facts are explained by general laws, and lower laws are explained by higher laws. The essence of scientific explanation is generalisation. Particular facts are explained by general laws. General laws are subsumed under still more general laws. Thus explanation is inductive in procedure.

Both explanation and induction involve assimilation. Explanation finds out similarities between new facts and known facts, new laws and known laws. It consists in bringing facts and laws into relation with known facts and laws. Induction also presupposes the Uniformity of Nature. It depends upon the similarity or community in essence among the particular facts about which a general law is established. Thus explanation and induction are allied to each other.

"All induction is progressive explanation." (*Welton*). It explains particular facts by empirical laws, and empirical laws by secondary laws, and secondary laws by primary laws. Explanation is generalisation.

8. Explanation and Deduction.

Scientific explanation involves deduction also. We deduce laws of less generality from laws of greater generality. Kepler's laws of planetary motion were explained when they were deduced by Newton from the Law of Gravitation. Resolution of a complex effect into the

laws of its separate causes involves deduction. The path of a projectile is explained, when it is deduced from the attraction of the earth, the initial force or the projectile tendency to move in a straight line, and the resistance of the air. Thus scientific explanation involves deduction.

9. Explanation and Classification.

"Explanation is a kind of classification ; it is the finding of resemblances between the phenomenon in question and other phenomena." *(Carveth Read).* It consists in finding out similarities among facts and laws. Many similar facts are subsumed under a general law. And many similar laws are subsumed under a more general law. Classification is the mental grouping of facts or phenomena according to their resemblances and differences. Thus explanation involves classification. Classification of objects and events according to their fundamental points of similarity is an aid to explanation.

10. Explanation and Hypothesis.

A hypothesis is an attempt at explanation. To explain a fact is to discover its *cause* and the *law* of its operation. But we cannot discover a cause or a law all of a sudden. We observe a number of particular facts and then hit upon a probable cause or law. The supposition as regards the probable cause or law is called a *hypothesis*. A hypothesis is framed to *explain* a number of particular facts observed. When this hypothesis is verified by the experimental methods, it becomes an Induction, and to verify a hypothesis is to arrive at a Scientific Explanation.

Therefore, a hypothesis is related to explanation ; it serves the purpose of explanation.

11. Explanation and Analogy.

Analogy is a source of discovery. It very often suggests a hypothesis. A hypothesis is intended to explain certain phenomena when the real cause or the law of its operation is not definitely known. Thus, Analogy, being a source of hypothesis, serves the purpose of Explanation. For example, after finding that the Earth resembles Mars, (i) in being a planet, (ii) neither too hot nor too cold for life, (iii) having an atmosphere, (iv) sea and land, etc., we conclude that Mars may be inhabited by living beings, like the Earth. Here, the Analogy between the Earth and Mars leads us to the hypothesis as to the existence of living beings in Mars. Thus, Analogy is an aid to Explanation. Analogy also helps us in explaining unknown things by comparing them with known things. It gives us a clear presentation of a thing which seems to be obscure. This is the importance of Analogy in the common sense. Thus, Analogy serves the purpose of both popular and scientific explanation.

QUESTIONS

1. What is Scientific Explanation ? Describe the various forms it assumes.

2. How does Scientific Explanation differ from Popular ? Describe and illustrate the different ways in which a phenomenon may be scientifically explained. Why cannot ultimate laws be explained ?

3. What is Scientific Explanation? Explain and illustrate the three modes of Scientific Explanation. Indicate the limits of Explanation. Give instances of Illusory Explanation.

4. "The object of science is to explain." Discuss the statement fully. Mention its three principal forms.

5. Illustrate some of the chief varieties of fallacious Explanation.

6. How is scientific explanation related to Induction and Classification?

7. What is the precise relation of Hypothesis to Explanation? Is Explanation possible in every case?

8. What is the relation of Explanation to Hypothesis and Induction?

9. What are the different forms of Scientific Explanation? Illustrate the explanation of empirical laws by higher laws.

10. What is the nature of Explanation? What are the principal errors incidental to it? Illustrate them. How can facts and laws be explained?

CHAPTER XI

THE LAWS OF NATURE

1. The Meaning of 'Laws' : Laws of the State, Laws of Nature, and Laws of Logic.

The word 'law,' in the juristic sense, means the *command* of a higher authority enforced upon the people by threats of punishment for their uniform obedience to it. The **Laws of the State** are of the nature of commands. They are the *commands* of the State which has power over the poeple. They imply *duties* on the part of the people to obey them. If they choose to disobey the laws, they are punished by the State. The political laws are man-made, changeable, and violable. They are made by men. They can be changed by the State. They may be violated by the people. They are of the nature of '*Must*'. They are imposed on the people for their *uniform* behaviour in conformity with them. The primary meaning of the word 'law', in the juristic sense, is a *command.* Its secondary meaning is *uniformity* of conduct in conformity with a law. Social laws also are of this nature. They are commands of the society, in its non-political aspect, enforced upon the people by threats of excommunication and other penalties.

The **Laws of Nature** mean the **Uniformities of Nature.** Here the word 'law' is used in a derivative sense. The Laws of Nature do not mean the commands of a higher authority. They mean the Uniformities of

Nature or the uniformities in the behaviour of nature. They mean uniform relations among the phenomena of nature. If certain phenomena always happen in a certain manner, they express a Law of Nature. The Laws of Nature are not man-made. They are objective : they exist in nature. They cannot be changed. They cannot be violated. The Law of Gravitation can neither be changed nor violated by men. The Laws of Nature are unchangeable and inviolable. They are of the natnre of '*Is*'. They are general statements about what is.

The **Laws of Logic** are rules for the attainment of the ideal of Truth. The **Laws of Ethics** are rules for the attainment of the ideal of Good. The **Laws of Æsthetics** are rules for the attainment of the ideal of Beauty. Logic, Ethics, and Æsthetics are normative sciences. They seek to determine the nature of the Norms or Ideals. Therefore, the Laws of Logic, Ethics, and Æsthetics are normative. They are rules for the realisation of standards or ideals. They state what ought to be done. They express not what is, or what must be, but what ought to be. They are of the nature of '*Ought*'. They cannot be changed. But they can be violated. If we violate the Laws of Logic, we cannot attain truth. If we violate the Laws of Ethics, we cannot attain good. If we violate the Laws of Æsthetics, we cannot attain beauty. Thus, the Laws of Logic, Ethics, and Æsthetics are unchangeable but violable.

Political Laws are in the form of *Must*. They are commands of a superior power. They are changeable and violable. The Laws of Nature are in the form of *Is*. They are not commands of a higher power. They are uniformi-

ties in the relations among phenomena of nature. They are unchangeable and inviolable. The Laws of Logic, Ethics, and Æsthetics are in the form of *Ought*. They are rules for the attainment of Ideals. They are unchangeable but violable.

2. Are the Laws of Nature subjective or objective ?

Some Logicians think that the Laws of Nature are *objective*: they exist in nature and operate independently of human knowledge. Man *discovers* the laws as they actually exist and operate in nature without being known. Others think that the Laws of Nature are *subjective*: they do not exist and operate in nature independently of human knowledge. They are man-made laws. They are *formulæ* which man *invents* to bind many facts together. They have no existence apart from human knowledge. They are shorthand formulæ to describe many phenomena of nature.

This view seems to be wrong. If the Laws of Nature are purely subjective inventions of men, they cannot adequately explain the phenomena of nature. The fundamental presupposition of science is the intelligibility of nature. Science is possible, if nature is intelligible. Nature is intelligible if it is governed by laws or uniformities among the phenomena of nature. If nature were a chaos of unrelated phenomena, science would be impossible. Therefore, it is reasonable to hold that the Laws of Nature are objective and discovered by men.

3. Classification of the Laws of Nature.

The Laws of Nature are mainly classified, according to their degrees of generality, into three kinds, *viz.*, (1) Axioms or Principles, (2) Primary Laws and (3) Secondary Laws. Secondary Laws, again, are of two kinds: (i) Derivative Laws, and (ii) Empirical Laws.

(1) Axioms or Principles.

Axioms or Principles are the fundamental postulates of all proof. They are presuppositions of all arguments. *Axioms are real, universal, self-evident propositions.* (i) They are *real* propositions as distinguished from verbal propositions. They are not mere verbal statements. They do not merely analyse the connotation of the subjects. They advance our knowledge. The proposition 'The whole is greater than its part' is not an axiom, because it is implied in the connotation of 'the whole'. (ii) Axioms are *universal* and *necessary* propositions. They are universally true of phenomena. They are true in all times and all places. Axioms concerning quantities are true of all quantities. (iii) Axioms are *self-evident*; they are beyond demonstration or proof. Their evidence lies in themselves; they cannot be proved; they are presuppositions of all proof. They cannot be derived from one another. They cannot be deduced from higher laws. They cannot be generalised from particular facts or other inferior laws. They can be derived neither from deduction nor from induction. The Laws of Identity, Contradiction and Excluded Middle are Axioms or laws of the highest generality. They are true of qualities as well as quantities. The Axioms of mathematics apply only to

quantities ; they apply also to time, space, mental and material phenomena. The Law of Causation applies to concrete phenomena only ; it is true of the phenomena of nature and mind. It cannot be derived from the Mathematical Axioms. It is the presupposition of all the special sciences dealing with the different departments of the world. "Axioms are the starting point of all deduction and the goal of all generalisation." (*Carveth Read*).

(2) Primary or Ultimate Laws.

Next to Axioms, there are Primary or Ultimate Laws. These are less general than the Axioms. They are proved with the help of the Axioms. They are not self-evident. They depend upon the Axioms for their proof. They are true of concrete events. "They are universally true only of certain forces or properties of matter, or of nature under certain conditions". (*Carveth Read*). They are the highest generalisations of the different sciences. The Law of Gravitation, in Astronomy ; the Law of Definite Proportions, in Chemistry ; the Law of Conservation of Energy, in Physics; the Law of Heredity in Biology ; the Law of Relativity, in Psychology, are the Primary Laws. These Laws cannot be deduced from higher laws. They are the limits of explanation.

(3) Secondary Laws.

Next to the Primary Laws, there are the Secondary Laws. They are less general than the Primary Laws. They result from a combination of Primary Laws under certain definite conditions. They are the '*media axiomata*'

(middle axioms) of Bacon. They are intermediate generalities. They are in touch with concrete events. They are regarded by Bacon as the steps for ascending to the Primary Laws. Bain points out that we can deduce the Secondary Laws from the Primary Laws, and thus descend from the Primary Laws to the Secondary Laws.

The Secondary Laws are divisible into two kinds, *viz.*, *Derivative Laws* and *Empirical Laws.*

(*i*) **Derivative Laws.**

Derivative Laws are those Secondary Laws which have been deduced from, or analysed into, Primary Laws. The theorems of Euclid are Derivative Laws because they have been deduced from the axioms and postulates. The laws of movements of planets, the law of terrestrial gravity, and the law of the tides have been deduced from the Primary Law of Gravitation. So they are Derivative Laws. *The Laws proved by the Method of Difference are Derivative Laws because it proves a causal connection.*

(*ii*) **Empirical Laws.**

Empirical Laws are those Secondary Laws which are believed to be deducible from, or resolvable into, Primary Laws, but which have not yet been deduced from, or resolved into, Primary Laws. Firstly, the Empirical Laws are Secondary Laws; they are less general than the Primary Laws. Secondly, they are believed to be deducible from the Primary Laws. Thirdly, they have not yet been deduced from the Primary Laws. Fourthly, they are generalisations based upon *Inductions by Simple Enumeration* or the *Method of Agreement.* Lastly, they are not Explanatory Laws. *They are merely Descriptive Laws:*

they describe the behaviour of facts. They do not explain the behaviour of phenomena or the behaviour of their cause. For example, the general propositions such as 'Scarlet flowers have no fragrance,' 'Quinine is a medicine for malaria,' 'The ruminating animals are cloven-footed, etc.,' are empirical laws. Their causes or conditions are not yet known. Inductions by Simple Enumeration are based on uniform and uncontradicted experience. They only show that two phenomena are invariably found together. They cannot prove any causal connection between them. The Method of Agreement eliminates the irrelevant circumstances, and suggests a causal connection between the two phenomena which are invariably found together. But it cannot conclusively prove a causal connection because it is frustrated by the possibility of Plurality of Causes. Therefore, the Empirical Laws are probable, while the Derivative Laws are certain.

There is no absolute line of demarcation between Empirical Laws and Derivative Laws. What is now an Empirical Law may be a Derivative Law afterwards. Thus, when Kepler announced that planets move in elliptical orbits after observing their positions, the statement was regarded as an Empirical Law. But when Newton deduced the same result afterwards from the Law of Gravitation and the projectile tendency of the planets, the Empirical Law became a Derivative Law. The rise of water in pumps was at first an Empirical Law. But it became a Derivative Law, when the pressure of the atmosphere was discovered.

The distinction between the Derivative Laws and the Empirical Laws lies in that the former have been deduced from the Primary Laws, while the latter are believed to be deducible but have not yet been deduced from the Primary Laws. "Derivative Laws make up the body of the exact sciences, having been assimilated and organised ; whilst Empirical Laws are the undigested materials of science." (*Carveth Read*). The laws of the expansion of different bodies by heat, the laws of chemical combination, the laws of medicine, etc., are Empirical Laws. The deduction of Empirical Laws from Primary Laws is the major part of the explanation of nature.

4. Limited Application of Derivative and Empirical Laws.

The scope of Secondary Laws is limited. Both Derivative and Empirical Laws can be applied only to *similar* circumstances. They cannot be applied beyond the limits within which they have been found to be true. **Bain** says, "A Derivative Law, and still more an Empirical Law, must not be extended beyond the narrow limits of Time, Place, and Circumstance." **Carveth Read** says, "Secondary Laws can only be trusted in *adjacent cases* ; that is, where the circumstances are similar to those in which the laws are known to be true."

A Derivative Law is deduced from a Primary Law or a combination of Primary Laws under definite circumstances. It will be true wherever the same forces are present in the same collocation of circumstances, provided there are no counteracting conditions. Water can be

pumped to about 33 feet at the sea-level on earth. It is a Derivative Law. Can it be extended to Mars ? It depends upon whether there are liquids in Mars similar to water ; whether there is an atmosphere of equal height and density, and consequently, of equal pressure there. If there is no atmosphere, there can be no pumping ; if the pressure of the atmosphere there is less than ours, water, such as ours can only be pumped to a less height than 33 feet.

An Empirical Law has not yet been deduced from a Primary Law. Its conditions are not yet known. So it can be extended at best only to *adjacent cases*. "It is an empirical law that the temperature of the earth increases, as we descend, at a nearly uniform rate of 1° F. to 50 feet of descent. This law has been verified by observations down to almost a mile. We might extend the law inferentially to the *adjacent* depths, as far perhaps as several miles ; but we are not at liberty to extend it to the centre of the globe. We do not know that the requisite collocations extend so far."[1] (*Bain*).

An Empirical Law should not be applied beyond the limits of time, place, and circumstances within which it has been found to be true. The laws of medicine are purely empirical. They should be applied strictly within the limits of observation. We cannot infer that two medicines of kindred nature will have the same effect ; "thus (chincona) bark and quinine are not interchangeable, although the one is the crude form and the other the

1 *Logic : Induction*, p. 107.

essential extract." (*Bain*). We cannot extend a mode of treatment to a similar disease. The treatment of Typhoid is different from that of Malaria. We cannot apply the same treatment to the same disease, in different persons.

The statistical laws are empirical laws. It is an empirical law that about 250 persons commit suicide in London every year. The law may be extended to the near future, when the moral habits of the people are expected to remain the same. But it cannot be extended to the remote future, when moral habits of the people may be different. The statistics of mortality show that there is a close correspondence between the rate of mortality and the density of the population. A high degree of longevity is found in thinly populated districts in spite of poverty ; and a high degree of mortality is found in the most crowded parts of cities. We should not extend this empirical law to the animals which do not equally require pure air like men. All animals require oxygen, but some require it in a smaller quantity, and are indifferent to impure gases ; they require a warm climate and opportunities of better food more than pure air. So, the law of mortality among men may not apply to the animals differently constituted from men.[1] Therefore, the scope of Empirical Laws is very limited.

5. Other kinds of Secondary Laws.

A. Secondary Laws are divided according to their constancy into (1) *Invariable Generalisations* and (2) *Approximate Generalisations.*

1 *Ibid* pp. 109—10.

(1) Invariable Generalisations are universally true of events as far as experience goes. They express general relations among phenomena within the limits of experience. For example, the proposition 'All material bodies fall to the earth' is an invariable generalisation.

(2) Approximate Generalisations fall short of universal propositions. They are of the form 'Most X's are Y'. The following propositions are approximate generalisations: 'Most metals are solid at ordinary temperatures'; 'Most arctic animals are white in winter'; 'Most cases of plague are fatal'; 'Most men are selfish'. Some of these are empirical laws ; they are based on experience ; they have not yet been deduced from primary laws. For example, 'Most metals are solid at ordinary temperatures.' Others are partially derivative laws. For example, the approximate generalisation 'Most arctic animals are white' is deduced from the law that the white colour protects the arctic animals from the other wild animals because they can easily conceal themselves in the snow.

Approximate generalisations are probable. They can be turned into universal propositions, if we can explain all the exceptions. 'Most arctic animals are white' can be turned into a universal proposition thus : 'All arctic animals are white, unless (like the raven) they need no concealment either to prey or to escape.' Here the exception is accounted for by a cause. Or, we may convert the approximate generalisation into a universal proposition by including the conditions on which the phenomenon depends, thus : 'All arctic animals to whom concealment is essentially necessary are white.'

In the domain of *science*, approximate generalisations may be converted into proportional statements based on statistics. 'Most persons inoculated against Typhoid are immune from the disease.' If it is found by collecting statistics that 80 per cent. of inoculated persons are immune from Typhoid, we can safely infer that inoculation is a preventive of the disease. Thus approximate generalisations are useful in science. They lead to universal truths.

In *Politics*, approximate generalisations are of great value. Social and political phenomena are extremely complicated. It is difficult to get universal truths regarding these phenomena. So we should be satisfied with approximate generalisations and legislate on the basis of propositions true of the majority of people.[1]

B. Secondary Laws are divided into the *Laws of Succession* and the *Laws of Co-existence.*

(1) Laws of Succession.

Laws of Succession are either (1) of direct *causation* (*e. g.*, 'fire burns,' 'water quenches fire,' etc.); or (2) of *the effect of a remote cause* (*e. g.*, 'Good rainfall is the cause of a good harvest,' 'Bad harvest tends to raise the price of bread,' etc.); or (3) of *the joint effect of the same cause* (*e. g.*, 'Day follows night' and 'Night follows day,' etc).

(2) Laws of Co-existence.

Laws of Co-existence are of several classes. (1) Some Laws of Co-existence are based on the *Method of Agreement*

1 Carveth Read: *Logic*, pp. 292—93.

(*e.g.*, 'All gravitating bodies are inert'). They are concerned with fundamental properties of bodies. (2) Some Laws of Co-existence are concerned with the *properties of Natural Kinds*. Natural kinds are those classes that agree among themselves and differ from others in numerous properties. The minerals, and the species of plants and animals are Natural Kinds. Numerous important properties co-exist in each of them. For example, gold is a metal of yellow colour, high specific gravity, atomic weight 197'2, high melting point, great malleability, low chemical affinities, etc. (3) Some Laws of Co-existence are concerned with *qualities not essential to any species*, and found in many different species. For example, 'Insects of nauseous taste have vivid (warning) colours'; 'White tom-cats with blue eyes are deaf.' (4) Some Laws of Co-existence relate to the *constancy of relative position*. For example, the distribution of land and water on the globe, the positions of the fixed stars in the sky, the orbits of the planets, etc., are relatively constant. The relative positions of sides and angles in Geometry are constant.

Geometrical co-existence is implied by the definitions, or it is deduced from the definitions and axioms. All other laws of co-existence are deducible from the Law of Causation. There is no general Law of Co-existence from which they can be deduced. When laws of co-existence cannot be derived fram causation, they can only be proved bv collecting examples and relying on the Uniformity of Nature. If no exceptions are found, we have an empirical law which may hold true within the limits of experience.

If exceptions are found, we have at most an approximate generalisation.[1]

6. The World as a System of Laws.

The world is not a chaos ; it is a harmonious whole of interconnected phenomena. The Unity of Nature is the presupposition of Science. If nature were a chaos of unrelated events, science would not be possible. Nature is a system of interrelated events. There is the reign of Law everywhere in nature. There is no chance anywhere.

Nature is conceived as consisting of various departments. In these departments the phenomena are governed by different laws. The laws are of different degrees of generality. Inferior laws are deduced from more general laws. Secondary Laws are deduced from Primary Laws. Primary Laws are the highest generalisations of different sciences. They cannot be deduced from any other higher laws. Thus, in Physics, there is a hierarchy of laws related to one another. The same truth holds good in Chemistry, Biology, etc.

The scientists believe that the laws in different departments of the world are not unconnected with one another. The physical laws are connected with the chemical laws. The chemical laws are connected with the physiological laws. The physiological laws are connected with the psychological laws. The psychological laws are connected with the sociological laws. The

1 *Ibid*, pp. 295–99.

sociological laws are connected with the moral laws. Thus, the whole world is a system of laws.

The Law of Conservation of Energy shows correlation of the different kinds of energy in the universe. Motion, heat, light, electricity, and magnetism are convertible into one another. The Law is extended by some to chemical affinity, vital force, and mental energy. Thus, physical energy, life, and mind are interrelated. The scientists believe that quantitative equivalence will be established among all these different kinds of energy in course of time.

The Law of Evolution also shows the unity and continuity in the evolution of the world. It seeks to break down the barriers between matter and life, and life and mind. It seeks to find out connections among the lower species and the higher species of animals. Cosmological evolution, biological evolution, mental evolution, social evolution, and moral evolution are all interconnected parts of the Law of Evolution.

Thus, the Law of Conservation of Energy and the Law of Evolution emphasise the systematic unity of the world.

7. Utility of the Laws of Nature.

The Laws of Nature connect multitudes of phenomena with one another and reduce nature into a system. They would be disconnected from one another without the Laws. The Law of Gravity of the earth connects all material bodies falling to the earth with one another. The Law of Gravitation (*i. e.* all material bodies attract one

another) connects the law of terrestrial gravitation, the law of ebb and tide, and the law of planetary motions with one another.

The Laws of Nature make the world intelligible to us. We cannot understand and explain the phenomena of nature unless we find out similarities among them and discover their causes and laws. Therefore, the phenomena of nature would be unintelligible to us if they were not governed by laws.

The Laws of Nature enable us to remember the infinite diversity of the phenomena of nature by connecting them together. We cannot remember the numerous particular facts of nature. But when they are bound together by laws, we can easily remember them.

All laws have utility. But some laws have theoretical utility, while others have practical utility. The Primary Laws are of great theoretical value. They are the highest generalisations of the different sciences. They unify and systematise all the facts and laws in a particular department of nature. The Secondary Laws are of great practical value. They are in touch with concrete events. They are our guides in practical affairs of life. They are the intermediate steps between Primary Laws and particular facts. We ascend from facts of nature to Primary Laws through them. And we descend from Primary Laws to concrete phenomena through them. Derivative Laws are of greater value than Empirical Laws, because they have already been deduced from Primary Laws. If we cannot deduce Secondary Laws from Primary Laws, we have to remain satisfied with Empirical Laws.

The Secondary Laws cannot be applied beyond the limits of time, place, and circumstances within which they have been found to be true. Empirical Laws can be extended only to adjacent cases. Derivative Laws can with greater certainty be extended to similar circumstances. The greater part of explanation of nature consists in deriving Empirical Laws from Primary Laws.

QUESTIONS

1. What is a Law ? Distinguish clearly between the following kinds of Laws and add examples :—

Laws of State, Laws of Thought, Empirical Laws, Laws of Nature.

2. Classify the Laws of Nature and give examples.

3. Distinguish between :— (*i*) Axioms and Primary Laws, (*ii*) Primary and Secondary Laws, and (*iii*) Derivative Laws and Empirical Laws. Give examples.

4. What is meant by a Law and a Law of Nature ? Explain Primary, Secondary and Empirical Laws. Give examples. Is the distinction between Derivative and Empirical Laws absolute ?

5. Explain and illustrate the different forms of Laws.

6. What are Laws of Nature ? Define and exemplify Ultimate, Secondary, Derivative and Empirical Laws, showing their relations to one another. To which class do those laws belong which are founded on the Method of Agreement ? Give your reasons with examples.

7. Mention the different methods of classifying secondary laws that have been adopted.

8. What is a Law ? Distinguish a Law of the State, a Law of Nature, and a Logical Law, illustrating your meaning by examples. Science must assume that Nature is subject to Law. Explain why it must be so.

9. What do you mean by an Empirical Law ? Show why it can be extended only to adjacent cases.

10. What do you mean by the expression that the world is a system of Laws ?

CHAPTER XII

PROCESSES SUBSIDIARY TO INDUCTION
CLASSIFICATION

1. Induction, Classification, Definition and Naming.

In Induction we pass from particular facts to a general truth. It is based on the *community of essence* (or the Uniformity of Nature) and the principle of *ground and consequent* (or the Law of Causality). For example, we can prove that 'all men are mortal' from the particular facts, *e. g.*, John, Jones, and James are mortal, only if we know that they have community of essence or they belong to the same class. And the arrangement of individuals into classes is called *Classification.* Classification of particular phenomena of nature helps us in discovering the Laws of Nature. Thus, Classification is subsidiary to Induction.

Classification is based upon Definition. One class is distinguished from the other classes, because the individuals belonging to that class have fundamental and essential points of community which constitute its *Definition.* Classification is the arrangement of individuals into classes according to their fundamental resemblances. Fundamental and essential points of similarity constitute the connotation of a class. Definition is the explicit statement of the connotation of a term. Thus, Classification is based upon Definition.

Definition, again, is very closely connected with Naming. When we determine the definition of a class by finding out its common and essential qualities, we assign an appropriate name to it in order to retain it in a convenient form and communicate it to others.

We arrive at the definition of a class by observing different individuals of the class and comparing them with one another. Thus, Definition is an inductive process. In Classification too we arrange individuals into classes, and the lower classes into higher classes. So this also is an inductive process. Thus, Classification, Definition and Naming are subsidiary to Induction.

2. The Nature of Classification.

Classification is a mental grouping of facts or phenomena according to their resemblances and differences, in order to serve some purpose.

This definition of classification implies the following characteristics :—

(*i*) Classification is the systematic arrangement of *individual* objects or facts into groups or *classes*, and these classes again into higher classes. It is an *Inductive* process.

(*ii*) Classification is a *mental* process of arranging individuals into classes, and lower classes into higher classes. It is a *mental* grouping ; it does not mean actual, physical arrangement of individual things in space and time as is done in a museum or a picture gallery. Physical grouping is the expression of mental grouping or classifica-

tion. Science, and consequently Logic, are concerned with classification in the sense of mental systematisation.

(*iii*) Classification is based on certain points of *similarity* and *difference*. Individuals are arranged into different classes according to their resemblances and differences. Those objects which resemble one another are placed under one class, while those which differ from one another are placed under other classes.

(*iv*) Classification is made in order to serve some *purpose*. It either serves the *general* purpose of knowledge or it serves a *special* or definite purpose.

We classify plants in Botany in order to advance our knowledge. We may also classify plants for the purpose of gardening. Classification can never be made without a purpose.

Individual animals are classified into cows, buffaloes, cats, dogs, lions, tigers, jackals, wolves, etc ; of these, cows and buffaloes are arranged under one class (*e. g.*, the bovine species); cats, lions and tigers under another class (*e. g.*, the feline species) ; dogs, jackals, and wolves under another class, (*e. g.*, the canine species). Here, therefore, we classify the animals according to their resemblances and differences into different classes. These classes, again, we may arrange under a higher class (*e. g.*, vertebrates).

3. Classification and Division.

Classification and Division both consist in systematic arrangement according to resemblances and differences ; but they essentially differ from each other. Classifi-

cation is an *Inductive* process, while Division is a *Deductive* process. Classification consists in arranging *individual* objects into groups or classes according to their resemblances and differences and these classes into higher classes, until we reach the highest class. Here, we proceed from the particular to the general or from the less general to the more general. Division consists in dividing a higher class into lower classes, and these lower classes, again, into still lower classes, until we come to the lowest classes or *infima species.* Here, we proceed from the more general to the less general. Therefore, Division is sometimes called Deductive classification. Thus, classification is an inductive process, while division is a deductive process. Classification is sometimes called Inductive classification.

Classification is a *material* process, while Division is a *formal* process. In classification we actually observe the individuals and mentally arrange them into different groups according to their points of similarity and differences. When classes have already been formed by the inductive process of classification, we can divide higher classes into lower classes according to the formal rules of division on the basis of the knowledge already acquired.

In Division the terms 'Genus' and 'Species' are entirely relative to each other ; the same class which is a genus in relation to the lower class is a species in relation to the higher class. But in Classification their meanings are fixed ; they have fixed positions in a gradation of classes which are represented by the terms, *e. g.*, (*i*)

Kingdom, (*ii*) *Sub-kingdom*, (*iii*) *Class*, (*iv*) *Sub-class*, (*v*) *Division*, (*vi*) *Order*, (*vii*) *Section* or *Family*, (*viii*) *Genus*, (*ix*) *Species* and (*x*) *Variety*, of which *Kingdom* is the highest group and *Variety* is the lowest group.

4. The Different Kinds of Classification.

Classification is of two kinds, namely, (1) Natural Classification and (2) Artificial Classification.

(1) Natural or Scientific Classification.

It is based on the most deep-seated or *fundamental and essential points of similarity* among the individuals. It is generally based on **Mill's doctrine of Natural Kinds.** According to this doctrine, there are certain Natural Kinds (*e. g.*, minerals, plants and animals), which constitute distinct classes in nature ; they differ from one another in numerous and important points, and the members belonging to the same class resemble one another in numerous and important points. Natural Classification, therefore, recognises the fixed classes of nature. It is mental grouping of objects according to their actual affinities. It is otherwise called scientific classification or philosophical classification. It serves the general purpose of knowledge. For example, when animals are classified into vertebrates and invertebrates, we have Natural Classification because it is based on deep-seated points of similarity. The botanical classification of plants is based on real affinities.

(2) Artificial Classification.

It is based on *arbitrary or superficial points of similarity* among individual objects. Artificial classes are

formed by man to suit his requirements for a special purpose.

Artificial Classification, again, is of two kinds, *viz.*, (1) classification of a *limited* number of objects and (ii) classification of an *unlimited* number of objects. In the former we arrange individual objects into different groups according to certain *artificial* marks of similarity. When, for example, we arrange the books of a library, or the paintings of a certain picture gallery, into different groups, we fix upon certain *artificial* marks of objects for their classification. In the latter kind of artificial classification we arrange objects into different groups according to certain *natural* characteristics which are superficial. The Linnæan classification of plants according to the number of stamens and pistils they possess, represents this kind of artificial classification.

Both these kinds of artificial classification are of great practical use to us. When, for example, we classify plants into flower plants, vegetables, herbs, weeds, etc., for the purpose of gardening, the classification, though artificial, serves a useful purpose. And even for scientific purpose it is sometimes useful. When the perplexities of natural objects are too great to admit of natural or scientific classsfication, we are compelled to fall back on some kind of artificial classification, because it helps us to remember them easily. In this sense, the Linnæan classification of plants is of great use.

Some logicians hold that the distinction between Natural Classification and Artificial Classification is arbitrary. In one sense, all classification is artificial, because

it is made by man. We arrange individuals into classes, and these classes into higher classes. We mentally group them according to their resemblances and differences. Natural or Scientific Classification is made by man and therefore artificial. We select the essential resemblances and arrange individuals into classes according to them. In another sense, *all classification is natural*, because it is based upon resemblances which exist in nature. Natural Classification is based upon numerous and important points of similarity which exist in nature. Artificial Classification also is based upon superficial resemblances which exist in nature. Therefore, it is arbitrary to distinguish between Natural Classification and Artificial Classification.

This criticism unnecessarily indulges in hair-splitting arguments. All classification is based on resemblances which exist in nature, and is a mental grouping of objects according to those resemblances. But there is a distinction between *essential* points of similarity and *superficial* points of similarity. Therefore, it is not illogical to distinguish between Natural Classification and Artificial Classification. It serves a useful scientific purpose.

5. The Rules or Conditions of Classification.

(1) *Place together in classes those things that possess in common the most numerous and the most important qualities. This is the golden rule of classification.* To classify objects merely by reference to their *superficial resemblances* (such as colour, size, form, etc.), however useful it may be for practical purposes, is scientifically useless.

(2) *Arrange the classes according to the degree of their affinity*. Connect those classes, which have the greater resemblance, and separate those which have the greater difference. The greater the affinity between two groups, the greater the proximity between the two in point of descent. And the greater the difference, the greater the distance between the two.

(3) *Graduate the classification upwards.* Arrange smaller classes under higher classes, and these classes under still higher classes, and continue the process until a comprehensive class or kingdom is reached. Such a classification reveals the mutual relations of the classes according to their fundamental points of similarity and difference.

6. Classification by Series.

We have seen that in classification we have not only to arrange individuals into classes, but also to classify the classes or arrange them under higher classes. We have to put those classes together which have the most common characteristics and are separated from other classes by the greatest number of differences. *So we pass through a gradation of classes until we reach the highest class.* The more we rise in the graded series of classes, the fewer become the common attributes among the wider classes, but at the same time more important and fundamental. By 'fundamental qualities' we mean those attributes which give rise to the greatest number of other attributes. *Classification by Series is the arrangement of classes of objects into a series, which possess a particular quality in varying degrees.* Plants, animals and men may be classified into a

series according to the varying degrees in which they possess life.

7. Mill's doctrine of Natural or Real Kinds.

Natural or Scientific Classification is based upon Mill's doctrine of Natural or Real Kinds. According to **Mill,** there are certain *fixed* classes in nature, which are fundamentally different from one another. *The members of these classes agree among themselves and differ from others in an indefinite number of fundamental or important attributes.* These fundamental and distinctive qualities peculiar to the different classes are fixed for ever; they cannot be modified in the course of nature. These *fixed* classes of nature are called by Mill the Natural or Real Kinds. For example, minerals, vegetables and animals are Natural Kinds. Dogs, horses, cows, etc., are natural kinds. They are fixed and immutable; they cannot merge into one another. These natural classes are recognised by Natural or Scientific Classification.

8. Classification modified by the Theory of Evolution.

The **Evolutionists** deny the existence of Natural Kinds or *fixed classes* in nature. According to them, the different species of animals are not fixed classes separated from one another by impassable gulfs; they are not essentially distinct from one another; they are but different developments out of the same stock under varying conditions. They represent but different stages of the evolution of the same stock; higher species have been evolved from the lower species in course of time. The

different species of plants also are not essentially distinct from one another. They also are evolved from the same stock. Hence, the Evolutionists lay stress on **Serial Classification** based on the community of descent.

The doctrine of Evolution has transformed the nature of Scientific Classification. "Under the influence of this conception the aim of classification has been completely revolutionised. Whereas formerly the realm of organic life was assumed to consist of a definite number of species which could be separated from one another by definite marks until the whole number of species had been enumerated and described, now, as it exists at any given moment, it is considered rather as the result of *descent from a common ancestry* with the modifications which successive ages have witnessed. The ideal of the older classifications was that of a formal division in which the highest genus was so divided that the sub-classes were mutually exclusive and at the same time co-extensive with the whole ; the aim for the newer is rather the construction of a *genealogical tree* which will just surely include every member of the family.... The process of evolution is not yet exhausted. Present species are liable to modification or even to extinction, and there is the possibility of new forms being evolved."[1] Thus, there are no Natural Kinds in nature.

9. Is Classification by Type or by Definition ?

There is a controversy between Mill and Wheweil on this question. **Mill** holds that we should classify objects

1 *An Intermediate Logic*, pp. 82-84.

according to their most fundamental and essential points of similarity or *definition*. **Whewell,** on the other hand, holds that we should classify objects by reference to their *types*. According to Mill, classification is based on Definition. According to Whewell, classification proceeds by Type. He says: "Natural groups are given by Type, not by Definition." "A type is an example of any class, which is considered as eminently possessing the character of the class." The type is a representative member of a class, which possesses all the important characters and properties in a marked and prominent manner. We classify objects by selecting a type and gathering round it those individuals which resemble it. We may take the tiger as the type of the feline species, and gather round it the cat, the leopard, the panther, the puma, etc. We may select earth, water, and air as types, and then group other things round one or other of these types, according to their resemblances to it, and in this way we classify objects into solid, liquid and gaseous. "Natural Groups," says Whewell, "are best described, not by any Definition which marks their boundaries but by Type which marks their centre."

Mill rightly contends that Classification should be based on Definition, *i. e.*, most fundamental and essential attributes. Even Classification by Type involves classification by definition. How is Type known to be a type? A Type is said to be a representative member of a class, which embodies its important features in a most prominent manner. But what are those important qualities of the class? They constitute the definition of the class. Thus, a type is a type because it illustrates the definition of the

class. Hence classification by type implies classification by definition. But Mill admits that classification is often suggested by *type*, though it has to be corrected by *definition*.

Whewell's Method of Classification by Type represents the popular mode of classification. Ordinarily, we do not determine the fundamental and essential qualities of objects by observing and comparing them with one another and then arrange them into different classes according to their essential resemblances. We fix upon an eminent member of a class or type (*e. g.*, a tiger) and gather round it all individuals resembling it, and thus form a class. Mill's method of classification by definition represents the *logical* or ideal form of classification. Classification should always be based on definition, *i. e.*, numerous important points of similarity.

10. Use of Classification.

(1) Classification brings out the important points of *similarity* and *difference* among things, and enables us to *understand* them *clearly*; for understanding chiefly consists in assimilation and discrimination; it consists in perceiving and comprehending the resemblances and differences of things.

(2) Classification is an *abbreviated form of explanation*. We explain an object when we refer it to an appropriate class. We explain the facts and Laws of Nature when we assimilate them to other facts and laws. Thus, classification is allied to explanation.

(3) Classification is an *aid to memory.* It is impossible to remember the innumerable objects individually with their infinite peculiarities; but it is comparatively easy to remember them by reference to their classes. Classification rationalises the memory.

(4) Classification tends to *unify or systematise our knowledge.* It organises our ideas of innumerable objects into a system by arranging them in a definite order according to their resemblances and differences.

(5) Classification also *suggests hypotheses by analogy.* By bringing out the resemblances among individuals sometimes it suggests hypotheses and leads to the discovery of new laws.

11. Limits of Classification.

Classification is limited by the following conditions:—

Classification consists in arranging individuals under classes, and these classes under higher classes.

(1) The *summum genus* or the higest class cannot be brought under any higher class. Therefore it is a limit of classification.

(2) The *marginal instances* cannot be easily classified. They may as well be brought under one class as under the opposite class. Is, for example, sponge a plant or an animal? Is ether material or immaterial?

(3) *Composite bodies* like a granite, etc., in which constituents are combined in varying proportions cannot be easily classified. Extremely complex objects and phenomena do not admit of classification.

(4) *Varying phenomena* whose composition is not known cannot easily be referred to their classes. There are so many odours with infinite shades that they have not been classified with scientific precision.

12. Classification and Explanation.

Carveth Read says: "Classification is closely analogous to Explanation. Explanation has been shown to consist in the discovery of the laws or causes of changes in nature; and laws and causes imply similarity, or like changes under like conditions: in the same way classification consists in the discovery of resemblances in the things that undergo change. We may say that Explanation deals with nature in its dynamic, classification in its static aspect."

Both Explanation and Classification satisfy our intellectual curiosity,—the one pointing out the cause of an event, and the other referring an object to its appropriate class. They both tend to rationalise the memory, and to organise the mind in correspondence with nature.

Thus, explanation and classification, though analogous to each other, differ in the fact that the one is an *explicit* and fully-expressed mode of accounting for things, while the other is an *implicit* and condensed mode of accounting for things; and the one is concerned with phenomena or *changes* of things, while the other is concerned with *things* that are comparatively stable.

QUESTIONS

1. Define Natural Classification, explaining what is meant by an essential or important property as the basis of classification. What is the value of natural classification for induction ?

2. What is the connection between Classification and Induction ? What are the requirements of Scientific Classification ?

3. Distinguish between Natural and Artificial Classification.

4. What is Classification ? What is its place in Induction ? What modification is introduced in the notion of classification by the theory of Evolution ?

5. What is Classification ? How does it differ from formal Division ? What are the requisites of a Natural Classification ?

6. State and explain briefly the nature, the conditions and the value of Scientific Classification. How does Classification differ from Division ?

7. Explain Classification, natural and artificial. Explain and illustrate Classification by Series.

8. Is Classification based on Type or Definition ? What is the point at issue between Mill and Whewell ? Which of them do you think to be correct and why ?

9. Distinguish Natural and Artificial Classification. In what sense is all classification artificial ?

Explain :—

(*a*) Classification by Definition.

(*b*) Classification by Type.

10. Explain logical classification. In what sense is Natural Classification also artificial ? Distinguish Classification by Type from Classification by Definition.

11. Explain Classification, Natural and Artificial. Explain (*a*) Classification by Definition, (*b*) Classification by Type, (*c*) Classification by Series.

12. Show the Relation of Classification to Definition.

13. State and illustrate the principal rules for the right conduct of Classification.

14. Is a Natural Group determined by a Type or by a Definition ? Discuss this question.

15. 'The process of determining a Definition is inseparable from Classification.' Explain this.

16. What is meant by *Natural Kind* or *Class?* Give an account of Natural Classification explaining what is meant by 'essential' or 'fundamental' characters as basis of classification.

CHAPTER XIII

DEFINITION

1. Deductive Definition and Inductive Definition.

Deductive Definition consists in the clear statement of the entire connotation of a term. Inductive or Scientific Definition consists in *determining* the connotation of a class. The one is a *formal* process, while the other is a *material* process. *Definition, in its material aspect, consists in determining the precise meaning or connotation of a class by examining the particular instances.* Unless we ascertain the connotation of a class how can we clearly state it? So the material process of Inductive Definition precedes the formal process of Deductive Definition. And in order to determine the connotation (*i.e.* genus and differentia) of a class, we have to observe certain individuals belonging to that class and certain individuals belonging to the opposite class, and compare them with one another. In this way we find out the most fundamental and essential characteristics of a class, and these constitute the definition of the class. Thus Inductive Definition precedes Deductive Definition.

2. Real Definition and Nominal Definition.

A definition is *real*, when it states the connotation of a class of things actually existing in nature. For example, 'man' is defined as a rational animal. A definition is *nominal* or *verbal*, when it unfolds the connotation of

a term, without any reference to the actual existence of the objects denoted by it. For example, 'unicorn' is defined as a horse with a single straight horn, which does not exist in nature.

There is a hot controversy about the question whether we define a *thing*, or a *name*, or a *concept*. The **Realists** hold that we define *things* denoted by names. The **Nominalists** hold that we define *names* only. The **Conceptualists** hold that we define *concepts* or notions. We cannot define names only without reference to the concepts or notions expressed by them. Sometimes we do not define things actually existing in nature. But we always define *concepts* or notions which are expressed by names. Sometimes there are things actually existing in nature corresponding to them. Sometimes there are no things existing in nature corresponding to them. We may define concepts of imaginary things.

3. Substantial Definition and Genetic Definition.

A definition is *substantial*, when it states the connotation of the term defined. It unfolds the essential qualities implied by the term. A 'triangle' is defined as a plane figure bounded by three straight lines. It is a substantial definition, because it states the entire connotation of the term 'triangle.' A definition is *genetic*, when it indicates the way in which we can determine the connotation of a term. It describes the genesis or origin of the thing denoted by the term. A 'circle' is described from a centre so that the radii from the centre to the circumference may be equal to one another. It is a genetic definition, because it describes the mode of formation of a 'circle'. It does not say what a circle is, but how it is formed.

4. Material Conditions or Rules of Definition.

(1) *"Assemble for comparison the particulars coming under the notion to be defined".* (*Bain*).

This rule is known as the *Positive method* of definition. By the "particulars" we are not to mean every individual instance coming under a class, but *representative* instances sufficient to embrace the extreme varieties. It is physically impossible to examine *every* member of a class. So we should select for comparison only the representative members of the class to be defined. For instance, in order to define 'man', we have to compare certain typical members of the human species and find out their fundamental and essential qualities.

(2) *"Assemble for comparison the particulars of the opposed or contrasting notion."* (*Bain*).

This rule is known as the *Negative method*. In order to define the connotation of a class, we have to compare not only individuals belonging to this class, but also the individuals belonging to the opposite class. This enables us to discover the differentia of the class to be defined. Thus, in order to define 'man', we should compare not only certain persons but also cetain birds and beasts.

(3) *Definition should include only the fundamental attributes from which many other important attributes follow.*

Definition consists in determining the precise meaning or connotation of a class. And connotation includes only the fundamental or essential qualities of a class. To define a class by referring to its superficial or accidental features is to *describe* it. So we must reject the accidental

or superficial qualities and select only the fundamental or essential qualities in order to *ascertain* the definition of a class. For instance, we must not think of the possession of two hands or two legs as the definition of 'man', but rationality and animality which are the most fundamental qualities present in all men and absent in other classes.

The golden rule of definition is to determine *the most important and the most numerous points of similarity among the objects constituting the class to be defined.*

5. Difficulties in Definition.

It is contended by Whewell and others that Inductive Definition by reference to connotation is almost impracticable, because it is extremely difficult to determine the fundamental and essential points of similarity among all the members of a class. The difficulties in the way of Inductive Definition are the following:—

(1) The *number* of individuals constituting a class is *too large* to be observed and examined. Even the number of representative instances is too large to be adequately considered.

(2) There are some *marginal instances* which may as well be brought under one class as under its opposite. Is, for example, arsenic a metal or a non-metal ? Is jelly solid or liquid ? Is sponge a plant or an animal ? It is difficult to determine their definition.

(3) It is very difficult to ascertain which of the numerous qualities found in the individuals belonging to the same class are *fundamental and essential.*

6. Is Definition by Type or by Connotation?

To avoid the above difficulties, Whewell suggests **Definition by Type.** It consists in defining a class by referring it to a '*representative member*' of the class, which conspicuously exhibits its prominent qualities.

This view is unsound. The co-called Type is considered as a type because it embodies the *essential* features of the class in a prominent manner. Consequently, to know a type *as* a type is to determine the essential features of the class. And to determine the *essential features* of a class is to determine its *connotation*. Thus, definition by Type involves definition by Connotation. So Mill's doctrine of Inductive Definition or definition by connotation seems to be correct. Moreover, the marginal instances do not invalidate Inductive Definition since they are but exceptions to the rule.

7. The Relation of Classification to Definition.

Classification is based on definition. It consists in arranging individuals into groups, and these groups into higher groups according to their essential resemblances and differences. Classification and definition both depend upon observation and induction. Both are assisted by each other. In defining terms we are helped by classification because it gives us a definite knowledge of the different classes with their fundamental points of similarity and difference. On the other hand, definition renders classification more accurate and scientific by pointing out the essential points of similarity among the individuals and classes.

QUESTIONS

1. Exhibit the nature and use of Definition.

2. Indicate the material conditions (rules) of Definition.

3. Mention the difficulties that occur in the process of definition, and show how they are to be met, giving concrete examples.

4. Explain and criticise Definition by Type.

5. Distinguish between Real and Nominal Definitions.

6. What is a Genetic Definition? How does it differ from Substantial Definition?

CHAPTER XIV

NOMENCLATURE AND TERMINOLOGY

1. Definition, Classification and Naming.

We have already seen that Classification and Definition are connected with each other. Classification is based upon Definition. We arrange individual objects into classes, and these classes again, into higher classes according to their fundamental and essential resemblances which constitute their definition. Again, classification also facilitates the determination of Definition. We can ascertain the fundamental and essential qualities of a class, which constitute its Definition, when we observe its individual members, compare them with one another, and group them under a class. Thus Classification and Definition help each other.

Classification and Naming are intimately connected with each other. As we arrange individual objects and events into classes, and these classes into higher classes according to their resemblances and differences, we assign names to the classes formed. Nomenclature is a system of names for classes. As classification advances and new classes are formed and arranged in a series, new names are required for the new classes formed. Thus, a system of new names must be formulated to keep pace with the progress of classification. Again, Naming helps Classification. Names have a definite and precise meaning. They make our thoughts of objects and classes accurate.

When we have a system of names for individual objects and their parts, qualities, and actions, and also for different classes, we can classify objects and events with greater accuracy in future for the advance of knowledge. Thus Classification and Naming help each other.

Definition and Naming also are intimately connected with each other. A name always bears some meaning ; and this meaning is precisely determined by definition. Definition consists in determining the fundamental and essential points of community among the members of a class. When we have determined these common and essential qualities of a class, we group them together into a concept and assign a name to it in order to retain and remember it easily and communicate it to others. Names are expressions of general notions or concepts of classes which are the results of Definition and Classification. Therefore, Names may be regarded as representative symbols of Definition and Classification.

2. Thought and Language.

Thinking is expressed in language. Language is the expression of thought. Thought and language develop each other. Thought is aided by language. But thinking may be carried on without language.

1. *Language is the expression of thought.* We can record our thoughts in language and communicate them to others through language. When our thoughts are recorded in language we may use them in future, and others also may profit by them. Our knowledge is developed by social intercourse which is carried on through language.

2. *Language is an aid to thought.* Discussion and argument stimulate thinking. Ideas and thoughts are comparatively vague and abstract. They cannot be controlled easily. When we express them in words, we can easily control and manipulate them through their symbols. Words make thoughts precise and definite.

3. *Language saves thought.* Language is a thought-saving instrument. Ideas and thoughts are vague. Names are symbols ; they are definite and precise. Symbols can more easily be manipulated than mere ideas. Symbols may be substituted for ideas and manipulated more handily. Progress of mathematical thinking has been rendered possible by the use of symbols.

4. *Language is an aid to recall.* Ideas are vague but names are definite. So we cannot easily retain and recall those ideas to which we have not assigned any names. But we can easily retain and recall those ideas to which we have assigned definite names.

5. *Thought and language develop each other*. Development of thought is greatly aided by development of language. And development of language is greatly aided by development of thought. Definiteness of thought leads to definiteness of language, and new scientific names make for greater precision of thought.

3. Classification, Nomenclature and Terminology.

Classification consists in the systematic arrangement of individual objects into *classes*, and of these classes into higher classes. As new classes are formed, new technical

names are coined. Scientific names are essential to classification. Nomenclature is a system of *names* for *classes*. "No classification could long remain fixed without a corresponding nomenclature, and every good nomenclature involves a good system of clsasification."[1] Classification is the ground of Nomenclature. Again, Classification and Nomenclature are aided by Terminology. Terminology is a system of terms or *names* for the parts, qualities, and activities of the *individual* objects which constitute a class. Terminology makes our knowledge of individual objects definite and precise, and helps us in forming classes and formulating their names. Thus it is an aid to Classification and Nomenclature.

4. Nomenclature and Definition.

Nomenclature is a system of names for classes. Names are assigned to classes, not arbitrarily, but because they possess certain common and essential properties. Classification is based upon Definition, *i. e.*, common and essential properties. Classes are formed according to common and fundamental resemblances. And names also should be strictly defined; they should convey common and essential qualities of the classes. Thus Nomenclature is intimately connected with Definition.

5. Scientific Use of Names.

General names economise thinking. They are convenient symbols of an indefinite number of objects and qualities. They facilitate memory, understanding, and knowledge. They make for precision of thought and advance of knowledge. They are means of communication.

---

1 *An Intermediate Logic*, p. 86.

General names enable us to formulate general propositions. Scientific knowledge consists in discovering the laws of nature. The laws of nature are general truths. General truths are expressed in the form of general propositions. They register our own past experience and the collective experience of mankind. They register and preserve the Laws of Nature permanently for the use of mankind.

General names are instruments for economising language. They dispense with the necessity of having names for the infinite number of individual objects. General names epitomise all individual objects constituting the classes indicated by them. If there were no general names of classes, general propositions embodying the Laws of Nature would not be formulated. Therefore, general names are indispensable for the advance of scientific knowledge.

6. Requisites of Scientific Language.

Scientific names should be precise and systematic. They should convey definite meanings. They should suggest the connotation of the classes indicated by them. They should suggest the distinctive attributes of the species. They should be convenient instruments for expressing the general truths discovered by sciences. The requisites of scientific language are the following :—

(1) *Firstly, there should be an appropriate name for every important meaning.* It implies that there should be (i) an adequate ***nomenclature*** or system of ***names*** for all

classes of objects, and (ii) a comprehensive *terminology* to describe and explain the parts, qualities, and activities of the *individual objects* which constitute the classes.

(2) *Secondly, every general name should have a definite and precise meaning.* The name of a class should have a fixed connotation. It should be free from ambiguity. The scientific names should be accurately defined.

7. Nomenclature.

A Nomenclature is a system of names for classes. It is a system of names of all the classes of objects, formed by classification in different sciences. Nomenclature is based upon scientific classification. We arrange individual objects into classes, and these classes into higher classes in classification. We assign definite names to these classes and sub-classes, which constitute a scientific nomenclature. In Geology there are names for different classes of rocks and strata. In Chemistry there are names for different kinds of elements and compounds. In Botany there are names for various kinds of plants. In Zoology there are names for various species of animals.

8. Requisites of Nomenclature.

Any system of names will not serve the pourpose of science. The names should be systematically significant, and even elegant. They should have definite and precise meanings. They should not be clumsy. They should be efficient ; they should convey the maximum meaning with the minimum effort. There should be distinct names for the higher classes ; and the names of the lower classes

should generally be formed of these names and qualifying expressions. There are two main ways of doing this.

(1) "The names of the lower groups are formed by combining names of higher and lower generality."

(2) The names indicate relations of things by modifications of their form." (*Welton*).

In Botany, for instance, the genus has a distinct name, *e. g.*, *Geranum*, *Rosa*, etc. The species is marked by adding a *distinctive attribute* to the name of the genus, *e. g.*, *Geranium phæum*, *Geranium nodosum*, *Geranium sylvaticum*, *Geranium lucidum*, etc. Similarly, the field rose is called *Rosa arvensis*; the dog rose, *Rosa canina*, etc. Here the differentia is not necessarily added to the name of the genus. In Zoology, also, the names of the species are derived from the name of the genus by the addition of distinctive attributes. For example, the species of *Felidæ* are called *Felis leo* (lion), *Felis tigeris* (tiger), *Felis leopardus* (leopard), etc.

In Chemistry, the names of the compounds are formed by combining the names of the constituent elements, *e. g.*, Carbon monoxide, Carbon dioxide, Sodium chloride, Calcium carbonate, etc. Chemistry also employs symbols. H_20 (water) is a chemical combination of two parts of hydrogen with one part of oxygen. $CuS0_4$ (copper sulphate) is a chemical compound of copper, sulphur, and oxygen in certain proportions.

9. Terminology.

A Terminology is a system of terms or names which describe the parts, qualities, and activities of

individual objects. For example, stalks, leaves, flowers, fruits, trunk, branches, and roots, which describe the different parts of a tree, fall within terminology.

Terminology is a system of names for the parts, qualities, and actions of *individual objects.* "All the names which form a terminology are general names ; though, by their combination, we can describe individuals."[1] Nomenclature, on the other hand, is a system of names for *classes.* Head, hands, legs, heart, lungs ; colour, size, shape ; circulation, digestion, inhalation ; these names of parts, qualities, and actions fall within terminology. But mammalia, vertebrata, etc., which are names of different classes in Zoology, fall within Nomenclature. "A Nomenclature of a Science is a collection of names of *groups.* A Terminology is a collection of the names (or terms) which distinguish either the properties or the parts of the *individual objects* which the science recognises." (*Fowler*). Terminology is *descriptive* and *explanatory*, *while* Nomenclature is *classificatory.* But sometimes the two terms are indiscriminately used for each other to express the whole vocabulary of technical terms in any art or science.

10. Requisites of Terminology.

Terminology is a system of terms which describe and explain the parts, qualities, and activities of individual objects.

(1) Firstly, there should be a name for every *physical part* of an individual object. For example, head, hands, legs, heart, lungs, muscles, nerves, etc., are the parts of an

1 *An Intermediate Logic*, p. 87.

organism. The *calyx*, the *corolla*, the *stamens*, and the *pistils* are the parts of a flower.

(2) Secondly, there should be a name for every *metaphysical part or quality* of an individual object, and for its modes and varieties and degrees. For example, extension, size, shape, colour, smell, sound, touch, motion, weight are the qualities of a material object. Red, blue, yellow, green, etc., are various colours. Sweet, bitter, sour, salty, etc., are various tastes.

(3) Thirdly, there should be a name for every *activity* of an individual object. Birth, growth, decay and death are processes of an organism. Circulation, digestion, and inhalation are physiological functions of an organism. Differentiation, integration, and determination are the processes of evolution. Attention, perception, retention, recall, imagination, conception, judgment, reasoning are the processes of the mind.

11. Variations in the meanings of Names in Popular Use.

The scientific names have definite and precise meanings. They convey the fixed connotation of the classes denoted by them. But the names used by common people do not convey a fixed connotation. They have vague and uncertain meanings. They do not denote classes of objects. The meanings of names in common use undergo variation owing to accidental circumstances and their transitive application to new objects.

(1) Accidental circumstances.

A name generally implies the common properties of the objects denoted by it. But some other properties due to accidental circumstances may *casually* be found along with the common properties so frequently as to become associated with them. As the association becomes stronger, the accidental circumstances or qualities are gradually incorporated into the connotation of a name. Sometimes the accidental connotation wholly supersedes the original meaning, and becomes not merely a part of the connotation, but the whole of it. For example, the word '*gentleman*' originally meant simply a man born in a certain rank. Gradually it came to connote the accidental qualities found in persons of that rank. At last, it came to connote a certain standard of conduct, character, habits, and outward appearance in persons of all ranks, which were expected to belong to persons born and educated in a high social position. Thus accidental qualities became a part of the connotation of the name. But sometimes the accidental circumstances constitute the whole connotation of a name, and supersede the original connotation. For example, the word '*pagan*' originally meant a villager, the inhabitant of a *pagus*, or village. The people of villages were ignorant and uncultured ; they stuck to their old habits and prejudices ; so they did not readily embrace Christianity. But the people of the towns were more immediately under the direct influence of the government of the Christian Roman Empire. From this casual coincidence, the word '*pagan*' came to mean a worshipper of ancient divinities. At last, it came to connote heathenism ; it means now a 'non-Christian.' Thus

the accidental circumstance constitutes the entire connotation of the name.[1]

(2) Transitive Application of names.

Variations in the meaning of names are also due to their application to other objects associated with the objects originally denoted by them. We observe an infinite number of objects. But we have comparatively a few names. So when we observe new objects, we have a tendency to avoid coining new names and apply the names of familiar objects similar to them. Such a use of names is called their transitive application. For example, the word '*salt*' originally meant the familiar sea-salt; but gradually it came to mean various kinds of substances resembling sea-salt, such as Sodium carbonate (common soda), Calcium carbonate (chalk), Copper sulphate, Silver nitrate, etc.

The meaning of a name is altered either by *generalisation* or by *specialisation.*

(*i*) *Generalisation consists in increasing the denotation of a name.* A part of its connotation is gradually dropped, and it is applied to a wider range of objects. For example, the name '*oil*' originally meant only 'olive oil'; but now it has came to signify all kinds of oil, *e. g.*, mustard oil, cocoanut oil, ground-nut oil, etc.

(*ii*) *Specialisation consists in decreasing the denotation of a name.* An accidental quality is added to its connotation, and it is applied to a narrower range of objects. "Thus, '*magazine*', a store or receptacle, has been narrowed

1. Mill : *Logic*, IV. V. § 1—2.

to a periodical publication. '*Cake*' is specialized to pastry. '*Wit*' formerly meant intellectual power of any kind; Bacon, Milton and Newton were great wits. The modern tendency is to restrict it to the production of ludicrous effects, and even still further to the ingenious play upon words."[1] (*Bain*).

QUESTIONS

1. Determine the relation of Definition, Classification, and Naming to Induction.

2. What is the difference between Nomenclature and Terminology? What are the requisite conditions of a good Nomenclature and a good Terminology?

3. Exhibit the relation of Nomenclature to Definition and Classification.

4. What are the requisites of Scientific Language?

5. Distinguish between the functions of common names of objects and the names used in science. Explain the principles of Nomenclature used in any natural science.

6. Show how the meanings of names are altered by generalisation and specialisation. Give examples.

1 *Logic: Induction*, p. 175.

CHAPTER XV

FALLACIES

1. The Kinds of Inductive Fallacies.

Fallacies arise from the violation of logical rules. They may be either deductive or inductive. Fallacies of Deductive Inference are due to the violation of the rules of the different kinds of Deductive Inference or the ambiguity of language. Here we shall consider only Inductive Fallacies and Non-Logical Fallacies.

Inductive Fallacies are of two kinds, *viz.*, Inferential and Non-inferential. The main forms of **Inferential Inductive Fallacies** are the fallacies of *Causation, Generalisation,* and *Analogy.* The main forms of **Non-inferential Inductive Fallacies** are the fallacies of *Observation, Hypothesis, Explanation, Definition, Classification,* and *Nomenclature.*

Non-logical fallacies arise from (1) undue assumption of a premise, and (2) irrelevancy of the conclusion. Fallacies arising from undue assumption of a premise are of three kinds: (1) *Petitio Principii*; (2) *Falsity of a Premise*; and (3) *Many Questions.* Fallacies of *Ignoratio Elenchi* due to irrelevancy of the conclusion are (1) *Argumentum ad hominem*; (2) *Argumentum ad populum*; (3) *Argumentum ad verecundiam*; (4) *Argumentum ad ignorantiam*; (5) *Argumentum ad baculum*; (6) *Shifting the ground*: (7) *Non Sequitur*; and (8) *Hysteron proteron.*

2. Inferential Inductive Fallacies.

Inferential Inductive Fallacies arise out of the violation of the rules of Inductive Inferences. There are three kinds of Inferential Inductive Fallacies, *viz.*, ***Fallacies of Causation, Illicit Generalisation***, and ***False Analogy***.

(1) Fallacies of Causation.

A cause is the unconditional, invariable, and immediate antecedent of an event. It is the totality of positive and negative conditions. Causality is not co-existence but sequence. Fallacies of Causation arise in the following ways:—

(*i*) *To mistake Co-existence for Causation.*

Causation is unconditional, invariable and immediate sequence. It is not co-existence. Two phenomena co-existing at the same time should not be regarded as cause and effect. For example, when a man wearing an amulet and escaping shipwreck regards the amulet as the cause of his escape, he mistakes co-existence for causation. Here wearing an amulet and escaping are co-existent events. So the former should not be regarded as the cause of the latter.

(*ii*) *To mistake Causation for Co-existence.*

Sometimes we mistake causation for co-existence. Great towns spring up on the side of great rivers because they afford facilities for communication and trade. Thus great rivers are the cause of the great towns on their sides. If we regard it as merely a curious coincidence that great rivers flow past great towns, we mistake causation for co-existence.

(*iii*) *Post hoc ergo propter hoc.*

When we mistake any antecedent for a cause, we commit the fallacy of *post hoc ergo propter hoc* (after this, therefore, on account of this). Generally we mistake an immediate antecedent for a cause. But a cause is not only an immediate antecedent, but also an invariable and unconditional antecedent. For example, a comet appears in the sky and a famine breaks out ; hence the comet is regarded as the cause of the famine. Whenever we connect certain events with omens, dreams, influence of planets, etc., we commit this fallacy. The following arguments involve this fallacy :—

1. 'When beggars die, there are no comets seen ;
The heavens themselves blaze forth the death of princes.'

2. You brought a curse upon my house, for no sooner had you left it than the lightning struck my roof.

3. The terror ceased immediately on the death of Robespierre ; therefore Robespierre was the cause of the terror.

4. The flood was evidently due to the wrath of the goddess, since it began immediately after she had been slighted, and it subsided after propitiatory sacrifices.

5. During the retreat of the ten Thousand a cutting north wind blew in the face of the soldiers ; sacrifices were offered to Boreas, and the severity of the wind immediately ceased, which seemed a proof of the god's causation.

(*iv*) *To mistake a Remote Antecedent for the Cause.*

A cause is a group of immediate antecedents which are invariably and unconditionally followed by the effect. Scientifically, a remote antecedent is not a cause. When we argue that Napoleon's Russian expedition was the cause of his downfall, or trace the second Great War to

the treaty of Versailles, we mistake a remote condition for the cause. The following arguments involve this fallacy :—

1. A habitual drunkard who studied hard for the army in his youth has got shattered nerves; therefore the cause of his shattered nerves is his hard study in youth.

2. The success of Pundit Amar Nath Jha as Vice Chancellor of Allahabad University is due to his brilliant career as a student.

3. The present national awakening in India is due to the Non-Co-operation Movement in 1920.

4. The present spirit of Democracy in Europe is due to the French Revolution.

(v) To mistake one Condition for the whole Cause.

A cause is an aggregate of positive and negative conditions. Sometimes we mistake a positive condition for a cause. Sometimes we mistake a negative condition for a cause. But this is a partial view of the cause. When we think that the mean annual temperature of a place is entirely due to its latitude, we commit this fallacy. It depends also upon elevation, distance from the sea, proximity of mountains, etc. The following arguments involve this fallacy :—

1. A workman, carrying a burden, falls from a ladder, and s killed. Therefore, his death is due to the fall.

2. A man is crossing a river in a small boat ; a sudden squall of wind comes on, the boat founders, and the man is drowned. Hence the squall of wind is the cause of his death.

3. The burning of a fire depends on fuel and the application of a lighted match. Therefore, fire is brought about by these events.

Here the absence of moisture in the fuel (negative condition) and the presence of oxygen in the air (positive condition) are neglected.

4. Water boils at 212° F. at the sea level. Therefore, this temperature is the cause of boiling of water.

The boiling of water depends slightly on the nature of the vessel, but mainly on the temperature of the water, and the pressure of the atmosphere which varies at different heights.

(*vi*) *To mistake the Co-effects of the same Cause for Cause and Effect.*

Day and night are co-effects of the same cause, *viz.*, luminosity of the sun, roundness of the earth, rotation of the earth round its axis. But they may be regarded as the causes of each other. The flowing tide is an invariable antecedent of the ebbing tide, and is equal to it. So it may be regarded as its cause. But, in fact, the ebb and the tide are both due to the attraction of the moon. The following arguments involve this fallacy :—

1. Violent religious excitement or inordinate grief is followed by insanity. Hence insanity is due to either of the causes.

Here the symptoms and the disease both may be the co-effects of the same combination of physical and mental causes.

2. A student working hard before an examination suffers from insomnia. Insomnia is followed by headache. Hence insomnia is the cause of headache.

3. 'It was a general belief at St. Kilda that the arrival of a ship gave all the inhabitants *colds*. Dr. John Campbell took pains to ascertain the fact and to explain it as the effect of effluvia arising from human bodies ; it was discovered, however, that the situation of St. Kilda renders a north-east wind absolutely necessary before a ship can make the landing.' (*Parish*).

(*vii*) *To confuse Cause and Effect with each other.*

Sometimes we cannot determine which of the two

causally connected phenomena is the cause and which is the effect. We may mistake cause and effect for each other. The meteorologists have not been able to ascertain whether thunderstorms are the cause or the effect of heavy rain-fall, or whether the heavy rainfall in the centre of the cyclone is the cause or the effect of the cyclone. *(Fowler).*

(viii) To neglect Mutuality of Cause and Effect.

Sometimes the cause and the effect react upon each other so that it becomes difficult for us to ascertain which is the cause and which is the effect. "Habits of industry may produce wealth, while the acquisition of wealth may promote industry. Again, habits of study may sharpen the understanding, and the increased acuteness of the understanding may afterwards increase the appetite for study." *(Lewis).*

(ix) To mistake a Single Consequence for the Whole Effect.

To cure temporary lassitude by a stimulant, and bring about nervous depression ; to relieve distress in a locality by setting up an almshouse, and encourage idleness and pretence ; to encourage a new industry by protective duties, and thereby impoverish the rest of the country ; to gag the press, and so drive the discontented into conspiracy, etc., involve this fallacy. *(Carveth Read).*

(x) To neglect the possible Plurality of Causes.

The Plurality of Causes is not possible, if we take the cause and the effect both either in a generic sense, or in a specific sense. But very often we take the effect in a

generic sense and the cause in a specific sense, and thus admit the possibility of Plurality of Causes. The following arguments involve this fallacy:—

1. Quinine is a medicine for malaria. Therefore it is the only medicine for it.

2. Drink is often a cause of poverty, but to attribute poverty only to drink is to libel thousands of very respectable people who are poor.

(2) Fallacies of Illicit Generalisation.

When we generalise without adequate evidence, we commit the fallacy of Illicit Generalisation. It may be committed chiefly in the following ways:—

(*i*) *Inductions by Simple Enumeration.*

Inductions by Simple Enumeration are based on uniform and uncontradicted experience ; they are not proved by the Experimental Methods. There is neither analysis of the phenomena, nor separation of the relevant from the irrelevant circumstances, nor proof of any causal connection. Enumerative Inductions neglect negative instances. Therefore, they involve the fallacies of Illicit Generalisation and Non-observation. The following arguments are Inductions by Simple Enumeration involving these fallacies :—

1. Unfortunately all the men with whom I have been acquainted are selfish; how then, can I resist the conclusion that Man is selfish ?

2. Women as a class have not been hitherto equal in intellect to men. Therefore they are necessarily inferior to men.

3. Negroes have never been as civilised as white people sometimes are. Therefore it is impossible that they should be so.

4. I have liked all the books of Galsworthy I have so far read ; I shall, therefore, enjoy reading his latest play.

5. For a long time mummy was a favourite medicament. People took a pinch of the dust of a dead Egyptian in a pint of the hottest water they could bear to drink, and it did them a great deal of good. This, people thought, proved what a sovereign healer mummy was.

6. Apparently we cannot live without drugging ourselves in some way or other. Who is there who can do without the regular cup of tea, the cigarette, the betel leaf, the cocktail, the aspirin tablet, and much more dangerous things ? Modern life appears to be inacceptable without stimulants of some sort.

7. Modern civilisation is a noisy civilisation. Its progress has been marked by an increase in the variety of unnatural noises. Noisy aeroplanes, loud-speakers, gramophones, street noises, barking dogs, chimes of big clocks on public buildings, and motor horns are making conditions of living very trying in some big cities in the world.

8. A certain tourist who travelled up and down this country for a few months observed many underfed, diseased and uncared for cows in the streets and in *gaushalas* and *pinjrapoles*. She subsequently proclaimed to the world that she had seen with her own eyes how unkind the people of India were to the cow they professed to adore.

(ii) *Extending Empirical Laws beyond Adjacent Cases.*

Empirical Laws are true only within the limits of time, place, and circumstances within which they have been found to be true. They can be extended only to adjacent cases. But if we extend them beyond adjacent cases, we commit the fallacy of Illicit Generalisation. The following arguments involve this fallacy :—

1. In Russia the Revolution was brought about by the Bolshevists ; in China also, the Bolshevists had something to do

with the Revolution ; in India Bolshevist agents are said to be encouraging the revolutionary party. The natural conclusion seems to be that the French Revolution must have been engineered by Bolshevists.

2. Water boils at 212° F. at the sea level on earth. Therefore water must boil at this temperature in Mars.

3. 500 persons in a million have died of snake-bite for some years past in India ; therefore the same number will die of snake-bite in future also.

(*iii*) *Hasty Generalisation.*

When we observe a very small number of instances and generalise from them, we commit the fallacy of Hasty Generalisation. In Induction by Simple Enumeration we observe a large number of positive instances. In Hasty Generalisation we observe only a very small number of positive instances. In both there is no attempt at analysis or elimination or proof of any causal connection. Both involve the fallacy of non-observation also. The following arguments involve this fallacy :—

1. My father died at the age of 38 years. My grand-father and great-grand-father also died at the same age. Therefore I also shall die at this age.

2. All republics are liable to corruption. Look, for instance, at France and the United States. They are republics, and they have both shown tendencies to corruption.

3. Free trade must bring prosperity ; for England is the richest country in the world ; and this is just what you would expect if Free Trade brought prosperity.

4. I can trust no one in future, for my dearest friend has played me false.

(3) False Analogy.

The fallacy of false analogy arises from (1) wrong estimation of the force of analogy, (2) confusion of essential with inessential qualities, and (3) the use of metaphorical language. (Chapter VIII). The following arguments involve this fallacy :—

1. Woman is justly entitled to participate in the government of the State. For the government of the State is only a kind of national house-keeping. And all admit that woman has a genius for house-keeping.

2. A man closely resembles his photograph. Hence since the latter fades on being exposed to the sun, a similar exposure should have a corresponding bleaching effect upon the man.

3. The alchemists appear to have imagined that the same preparation by which they hoped to convert the baser elements into gold would cure all bodily diseases. Why should not the impurities of the human body be removable by the same means as the impurities of the metals ? (*Fowler*).

3. Non-inferential Inductive Fallacies.

Non-inferential Inductive Fallacies arise out of the violation of the rules of the processes which are subsidiary to Induction. They are the fallacies of Observation, Hypothesis, Explanation, Classification, Definition, Nomenclature and Terminology.

(1) Fallacies of Observation.

They are of two kinds, *viz.*, *Non-observation* and *Mal-observation*. (Chapter IV).

(*i*) The fallacy of **Non-observation** arises from overlooking *negative* instances. Inductions by Simple

Enumeration involve this fallacy. The following arguments involve this fallacy owing to neglect of negative instances.

1. This must be a good medicine, since there are over a hundred testimonials from persons who have been themselves benefited by its use.

2. The patent medicine must be very efficacious, for all the testimonials speak of the marvellous cures effected by it.

3. I do not consult physicians, for those that do so also die.

4. Charcoal is cheap among roof timbers after a fire, bricks are cheap in the streets after an earthquake, and famine-stricken people will work for next to nothing. Destructive agents like fire, earthquake, and famine are therefore economic blessings in disguise.

Here relevant circumstances are ignored. Fortunes are made more out of prosperity than out of calamities.

5. The armament firms thrive on war ; the glaziers gain by broken windows; the operating surgeons depend on cancer for their children's bread. Therefore, everywhere the prosperity of a Dives costs the privation of a hundred Lazaruses ; and fortunes are made out of destruction, waste, and disease.

(*ii*) The fallacy of Non-observation arises from overlooking the *operative conditions*. Sometimes we fail to analyse the phenomenon under investigation and observe the material circumstances that operate in bringing it about, and thus commit this fallacy. The following arguments involve this fallacy owing to neglect of material conditions :—

1. Since no beggars are to be seen on the streets of London there can be no indigent folk in that prosperous city.

Here the material condition that begging is prohibited by law in England is ignored.

2. The number of deaths in Calcutta per annum is greater than in Nagpur. Therefore Calcutta is more unhealthy than Nagpur.

The population of Calcutta is much larger than that of Nagpur. This material circumstance is overlooked.

3. The number of patients admitted into hospitals is much larger everywhere at present. Therefore, the health of the people has deteriorated.

4. The number of convictions of drunkenness has considerably increased. Therefore, the crime of drunkenness has much increased.

(*ii*) The fallacy of **Mal-observation** arises from *misinterpretation* of sensations or blending of perception with *unconscious inference.* When we mistake a rope for a snake, shell for silver, a post for a man, one man for another, we commit the fallacy of mal-observation. When we mix perception with unconscious inference, we also commit this fallacy. The following arguments involve this fallacy :—

1. We daily see with our own eyes that the sun rises in the morning, travels across the sky, and sets in the evening, while our planet remains stationary. Therefore it is certainly wrong to say that the earth moves round the sun.

We see different positions of the sun and infer from them that it moves round the earth. In fact, it appears to move round our planet. Actually it does not rise or set.

2. In ventriloquism we actually hear voices come from different parts of a building. So it is wrong to say that they come from the ventriloquist.

(2) Fallacies of Hypothesis.

A hypothesis must conform to certain conditions in

order that it may be regarded as legitimate. If it fails to satisfy the conditions, it is illegitimate. (Chapter V). The following arguments involve illegitimate hypotheses :—

1. The earthquake is due to some disturbance in the interior of the earth.

2. The earthquake is due to a huge bull's shifting the earth from one horn to the other.

3. The lunar eclipse is due to a huge monster's swallowing the moon.

4. A person suddenly talks incoherently and behaves like a different person. Therefore he has been possessed by a ghost.

(3) Fallacies of Explanation.

Scientific Explanation differs from Popular Explanation which is fallacious. If we regard familiar phenomena as simple, or repeat the facts in a different language, or try to explain primary laws, elementary experiences, primary qualities of matter, and infinite peculiarities of particular facts, we commit the fallacy of explanation. For example :—

1. Glass is transparent because we can see through it.

2. Opium induces sleep because it has a soporific virtue.

3. We see every day that a fire is kindled by contact with a lighted match. Hence it does not demand any explanation.

4. The Law of Conservation of Energy can best be explained by the constancy of God, the Creator of the universe.

(4) Fallacies of Classification.

Scientific Classification is based upon the most numerous and important points of similarity. If we

arrange individual objects mentally according to their superficial resemblances, we commit a fallacy. When Classification has been made, it should be tested by the rules of Division. (Chapter XII). For example :—

1. Bats. butterflies, and parrots fly. So we group them under the class of birds.

2. Cats, dogs, cows, and horses are domestic animals. So we regard them as species of the same genus.

(5) Fallacies of Definition.

We ascertain the Definition of a class by determining its common and essential qualities. If we include its accidental qualities in its definition, we commit a fallacy. When Inductive Definition is reached by observation and comparison of individuals, it should be tested by the formal rules of Definition. (Chapter XIII).

(6) Fallacies of Nomenclature and Terminology.

Scientific Names for classes must fulfil certain conditions. They must have a fixed and precise meaning. They must convey most meaning with least effort. They must not be clumsy. There should be a scientific term for every part, quality, and action of an object. If these conditions are not satisfied, we commit a fallacy. (Chapter XIV).

4. Non-logical or Material Fallacies.

These fallacies do not violate any formal rules of reasoning. They are concerned with the *subject-matter* of reasoning. One unfamiliar with the subject-matter

cannot detect errors in these arguments. Therefore they are called *material* fallacies. They arise out of (1) undue assumption of a premise or (2) irrelevancy of the conclusion or *Ignoratio Elenchi*.

I. Undue Assumption of a Premise.

Fallacies arising from *undue assumption of a premise* are of three kinds: (*1*) *Petitio Principii* (2) *Falsity of a Premise*; and (*3*) *Many Questions* (or *Complex Question*).

(1) The Petitio Principii.

This fallacy consists in assuming the conclusion which is to be proved. It is also called the fallacy of **Begging the Question.** Here we take for granted openly or covertly what we propose to prove. In all true reasoning the conclusion must follow from the premises. It must not be already contained in one of the premises.

Petitio Principii may be either *Simple* or *Complex*. It is called *Simple* when it is involved in a *single* argument. It is called *Complex* when it is involved in a *chain of arguments*. The complex form is called an *argument in a circle*.

(a) Simple Petitio Principii.

This fallacy consists in simply repeating the premise in different words.

(*i*) Glass is *transparent* because we can *see through* it.

(*ii*) Opium *produces sleep* because it has a *soporific* virtue.

(*iii*) You ought to give alms because it is a duty to be charitable.

(*iv*) A must be heavier than B, because A weighs B down.

(*v*) The human soul must be diffused over the whole body, because it animates every part of it.

(*vi*) This act is wrong because it is opposed to sound moral priuciples.

(*vii*) This problem is too difficult, and therefore no one will attempt its solution.

This fallacy occurs when the conclusion of a *single* syllogism is really contained in one of the premises. Thus :—

No fallible beings are infallible ;

All men are fallible :

∴ No men are infallible.

Here the conclusion seems to follow from both the premises. But really it is assumed in the minor premise which, when obverted, directly gives the conclusion. So there arises the fallacy of *Petitio Principii.*

(b) Complex Petitio Principii.

This fallacy occurs in a *chain of arguments.* It is also called **Argument in a Circle.** It occurs when a proposition is proved by another proposition, which is again proved by the first.

In the following example, the major primise of the first syllogism is proved by the second, and the major permise of the second by the first syllogism:—

(*i*) *All M is P ;*	(*ii*) *All S is P ;*
All S is M ;	All M is S ;
∴ *All S is P.*	∴ *All M is P.*

In this example there are only two syllogisms connected with each other. But there may be more than two syllogisms in the

chain of arguments in which the *same proposition* may occur in different parts of the train. For example:—

(*i*)	*All A is B ;*	(*iii*)	All A is D ;
	All B is C :		All D is E :
	∴ All A is C.		∴ All A is E.
(*ii*)	All A is C ;	(*iv*)	All A is E ;
	All C is D :		All E is B :
	∴ All A is D.		∴ *All A is B.*

In this train of syllogistic reasoning the final conclusion of the fourth syllogism is the same as the minor premise of the first. Therefore the final conclusion of the chain of arguments is already assumed in a premise from which it is drawn. Thus it is an argument in a circle. It is called an argument in a circle because the reasoning comes back to the point from which it started.[1]

(*i*) I will not do this act because it is unjust ; I know that it is unjust because my conscience tells me so, and my conscience tells me so because the act is wrong.

(*ii*) We know that God exists because the Bible tells us so ; and we know that whatever the Bible affirms must be true, because it is of divine origin.

(*iii*) To allow every man an unbounded freedom of speech is advantageous to the State, for it is highly conducive to the interest of the community that each individual should enjoy an unlimited liberty of expressing his sentiments.

(*iv*) "He talks with angels" one told me. "How do you know it ?" I said sceptically. "He himself admits it. But suppose he lies." "What ! a man who talks with angels is capable of a lie ?"

(2) Falsity of a Premise.

This fallacy occurs when one of the premises is false. The conclusion follows from the premises. If

1 P. K. Ray : *A Text-Book of Deductive Logic*, pp. 235-36.

one of the premises be false, the conclusion must be false.

(*i*) Flying animals are birds; bats are flying animals: therefore bats are birds. (Here the major premise is false.)

(*ii*) No communists believe in private income; all socialists are communists: therefore no socialists believe in private income. (Here the minor premise is false.)

(3) Many Questions (Complex Question).

This fallacy consists in combining many questions together to which a single answer ('yes' or 'no') cannot be given. Such an artifice is often resorted to by lawyers in cross-examining witnesses. They put complex questions to a witness, which he cannot answer by simple 'yes' or 'no' without prejudicing his position.

(*i*) 'Have you left off beating your mother ?

If you say 'Yes', it means that you were in the habit of beating your mother, and you have given up the habit. If you say 'No', it means that you were in the habit of beating your mother and still continue the habit. Both the answers compromise your position.

(*ii*) In what subjects did you fail ?

(*iii*) Have you given up drinking ?

(*iv*) Have you given up telling lies ?

II. Ignoratio Elenchi.

It means 'ignorance of confutation'. It consists in arguing beside the point or proving the wrong point. Any argument which is not to the point commits this fallacy. It consists in arguing in such a way that the conclusion does not overthrow the opponent's position. In disputation in order to overthrow our opponent we should prove the contradictory of his assertion. But if,

instead of doing this, we indulge in arguing beside the mark and establish a conclusion which is not the contradictory of the opponent's thesis, we commit the fallacy of *Ignoratio Elenchi.* There are several forms of this fallacy :

(1) Argumentum ad hominem.

It consists in showing inconsistency in the character, principles, or professed opinions of the opponent. It does not refer to the real matter under discussion. "In order to confuse an opponent, and discredit him with the audience, one may show that his character is bad, or that the views which he is now maintaining are inconsistent with his former professions and practice." (*Creighton*).

(*i*) Who are you to condemn inter-caste marriage, who, being a Brahmin, have married a Vaish girl ?

(*ii*) My opinions must be true, for none but a prejudiced person, like yourself, would wish to gainsay them.

(*iii*) This measure would be destructive of national prosperity, and I cannot adduce a more cogent argument than that, five years ago, you were yourself of the same opinion.

(*iv*) "In reply to the gentleman's arguments, I need only say that two years ago he advocated the very measure which he now opposes." (*Creighton*).

(2) Argumentum ad populum.

It consists in apealing to people's passions and prejudices rather than to their reason. It is an appeal to the gallery. It is often resorted to by mob orators who try to convince the audience of a proposition by working up their passions.

(*i*) Will you accept Darwin's theory ? Will you believe that your fathers and mothers are descendants of monkeys ?

(*ii*) If you oppose this measure the government will be defeated and the socialists will get into power. They will undermine the constitution of the country and increase the income-tax, etc.

(*iii*) Ladies and gentlemen ! Will you not vote for the Congress candidates ? Did they not court imprisonment and untold sufferings for you ? Did they not cheerfully submit to *lathi* charges and bayonet thrusts of the police ? Did they not gladly court even death for the sake of the country ? Will you vote for toadies who bartered away the soul of India for a mess of pottage ? Lo ! Mother India looks up to you with tears in her eyes for deliverance from her bondage.

(3) Argumentum ad verecundiam.

It consists in appealing to the feeling of reverence for authority of a respected person, or a book, or a memorable institution.

(*i*) How can slavery be condemned, when it was justified by Aristotle and sanctioned by the Christian Church ?

(*ii*) The theory of Evolution must be true, for it is upheld by Darwin and Herbert Spencer.

(*iii*) War cannot be condemned as an evil. Does not the *Gita* advocate war for a righteous cause ?

(*iv*) The writer is a historian of great learning. and if he denies the existence of God, what wise man will dissent from his opinion ?

(4) Argumentum ad ignorantiam.

It consists in taking advantage of the opponent's ignorance of the subject-matter of the argument. It "consists in trusting that the ignorance of the hearer will

lead to the acceptance as proved of statements which are by no means proved." (*Welton*).

(*i*) A physician who cannot diagnose a complicated disease tries to deceive his patient by telling him a big name of the disease and giving him a wrong explanation of it, knowing full well that he cannot make out anything at all.

(*ii*) A student of Logic may try to silence his opponent in disputation, who is innocent of Logic, by telling him wrongly that his argument commits the fallacy of illicit major.

(5) Argumentum ad baculum.

It is an appeal to brute force to silence the opponent. It is an 'appeal to the big stick.' It is an argument of the cudgel ! "To knock a man down when he differs from you in opinion may prove your strength, but hardly your logic." (*Stock*).

"A sub-variety of this form of irrelevancy was exhibited lately at a socialist lecture in Oxford, at which an under-graduate, unable or unwilling to meet the arguments of the speaker, uncorked a bottle, which had the effect of instantaneously dispersing the audience. This might be set down as the *argumentum ad nauseum.*" (*Stock*).

(6) Shifting the Ground.

This fallacy arises when a person unable to maintain his original position covertly changes the question at issue.

(*i*) When an Inspector of Schools demands an explanation from the Head Master of a school why the students of his school are hopelessly weak in Mathematics, he covertly changes the question at issue and says : 'My school is famous for teaching English.'

(*ii*) I cannot accept your opinion as true, for it seems to me that its general recognition would be attended with the most injurious consequences to society.

(7) Non Sequitur.

This fallacy arises "when the conclusion does not in any way follow from the premises, when, in fact, there is no logical connection between the two, anything being inferred from anything else."*

(*i*) "Pennsylvania contains rich coal and iron mines ;
Pennsylvania has no sea coast :
∴ The battle of Gettysburg was fought in that state."
(*Creighton*).

(*ii*) He must know a great deal, for he says little.

(*iii*) You must have met Mohan yesterday at Delhi, because he also went there yesterday.

(8) Hysteron Proteron.

This fallacy consists in inverting the natural or logical order. In it a cause is deduced from its effect or a premise is inferred from its conclusion. It is popularly known as putting the cart before the horse. Here we put first what should be stated last.

(*i*) "The whole of India and Bengal were in glee at the emperor's visit." Bengal is included in India. So it should have been stated first.

(*ii*) "We feel sorry because we cry, angry because we strike, afraid because we tremble." (*James.*) According to William James, first there is an organic expression, and then it is followed by an emotion. He commits the fallacy of of *Hysteron Proteron*.

*This fallacy should not be confounded with the fallacy of affirming the consequent or the fallacy of denying the antecedent.

CHAPTER XVI

ANALYSIS OF INDUCTIVE ARGUMENTS

1. Analysis of Inductive Arguments.

In order to test the validity of an inductive argument, at first we ought to analyse it fully and see what Inductive Method has been employed, and then find out whether the Method has been applied correctly or not. The following hints are given for the analysis of an inductive argument.

Read the argument a number of times very carefully. Find out the conclusion and the evidence in favour of the conclusion. (1) If *two* instances are compared, and from their partial identity further identity between them is inferred, regard the argument as analogical. Test the analogy in the light of its conditions. In an analogical argument the conclusion is *particular*. If the conclusion is *general*, find out if the evidence is based on observation or experiment. (2) If it is based on *observation*, ascertain if the argument is an Induction by Simple Enumeration or an application of an Inductive Method. An Enumerative Induction is based on mere enumeration of a *large* number of *positive* instances. Here there is no *variety* of instances or any attempt at analysis and elimination. (3) If the evidence is based on *observation*, and the general conclusion is drawn from a number of *positive* instances with one common antecedent and one common consequent,—the other antecedents and consequents varying, the argument is an application of the Method of Agreement. In the Method of Agreement there are a *variety* of positive instances and elimination of irrelevant circumstances. (4) If the evidence is based on *observation*, and the general conclusion is drawn from a number of *positive* and *negative* instances, the argument is an application of the Method of Double Agreement. (5) If the evidence is based on *experiment* and the

general conclusion is drawn from *two* instances, one *positive* and the other *negative*,—nothing being known by previous inductions,—the argument is an application of the Method of Difference. Here we must remember that *the other conditions must remain quite the same*, and the introduction of an antecedent is followed by the appearance of a consequent, and the elimination of an antecedent is followed by the disappearance of a consequent. (6) If the evidence is based on *experiment*, and the general conclusion is drawn from two instances,—one *positive* and the other *negative*,—the *negative* instance being derived from *deduction* from previous inductions, the argument is an application of the Method of Residues. It seeks to find out the cause or effect of a *residual* phenomenon. (7) If the evidence is based on *experiment*, and the general conclusion is drawn from a number of instances in which one antecedent and one consequent *vary* directly or inversely in *numerical concomitance*, the other circumstances remaining the same,—the argument is an application of the Method of Concomitant Variations. Sometimes this Method is based on observation. Then it is a variation of the Method of Agreement, and the other accompanying circumstances also differ from one another.

2. Fallacies in the Application of the Inductive Methods.

Fallacies arising from the application of the Inductive Methods are the fallacies of generalisation due to inadequate proof of causal connection which, again, is due to insufficient elimination of irrelevant circumstances.

3. The Method of Agreement.

This Method is vitiated by (i) observation of an insufficient number of instances, (ii) non-observation of negative instances, and (iii) possibility of Plurality of Causes and Intermixture of Effects.

(1) 'If we breathe on a cold metal or a stone, moisture condenses on it. The same phenomenon appears on a glass when ice-water is poured into it, and on the inside of windows when the

air outside gets colder suddenly. We may therefore conclude that condensation of moisture on a surface is due to its being colder than the surrounding air.'

Here we observe a number of positive instances. We observe a *variety* of *cold* substances (*e.g.*, a cold metal, a cold stone, a glass of ice-water, and the inside of windows suddenly cooled) exposed to moisture. Coldness is the common antecedent in the positive instances. We also observe the common consequent, *viz.*, condensation of moisture. All other circumstances differ. Therefore the common antecedent (*e.g.*, the surface of a substance being cooler than the surrounding air) and the common consequent (*e.g.*, condensation of moisture) are causally connected. The *Method of Agreement* is rightly employed here. But it cannot determine the nature of causal connection. It is a method of observation. So it cannot yield a certain conclusion.

(2) A conjurer produces wonderful results by different tricks on different occasions, taking care to wave his hand in each case. Therefore the waving of his wand is the cause of wonderful results.

Here we observe a number of positive instances. They agree only in having a common antecedent (*e. g.*, waving of a wand) and a common consequent (*e. g.*, wonderful results). So the waving of the hand is the cause of the wonderful results. The conclusion is wrong. The *Method of Agreement* is wrongly applied here. The waving of the hand is accidentally present. Different tricks of the conjurer (*e. g.*, sleight of hand) are the causes of different wonderful results. But these tricks are not observed. So there is the fallacy of *Non-observation.*

(3) 'Brewster took impressions from a piece of mother-of-pearl in a cement of resin and bees' wax, in balsam, in fusible metal, in lead, in gum arabic, in isinglass, etc. In all cases the same iridescent colour appeared. But the only character which these substances had in common was the form of the surface produced by the impression of the piece of mother-of-pearl. Hence the form of surface must be a condition of the iridescent colour'.

Here we observe a number of positive instances. They differ in all other circumstances except in having a common antecedent (*e. g.*, the form of the surface) and a common consequent (*e. g.*, the iridescent colour). Therefore they are causally connected. The *Method of Agreement* is rightly employed here. The conclusion is certain.

(4) 'Hot springs are irregularly distributed in various countries throughout the world—in America, Tibet, Japan, Iceland, the Azores, the Pacific Islands, etc. It is found, however, that they practically always occur in regions which are, or have been, scenes of volcanic activity.'

Here we observe a number of positive instances. They differ in all other circumstances except in having a common antecedent (*e.g.*, volcanic activity) and a common consequent (*e.g.*, the presence of hot springs). Therefore, volcanic activity in the interior of the earth is the cause of hot springs. The *Method of Agreement* is rightly applied here. But the conclusion is probable, because it is based on observation.

4. The Method of Double Agreement.

It is a method of Observation. It is vitiated by (i) insufficient elimination, (ii) non-observation of instances, and (iii) failure to determine the nature of causal connection.

(1) It is frequently observed that authors, statesmen, and big merchants have a poor hand-writing while petty clerks write most neatly and legibly. Therefore poor penmanship is caused by the influence of severe mental labour.

We observe a number of positive instances in which severe mental labour and poor hand-writing are present. We also observe a number of negative instances in which severe mental labour and poor hand-writing are absent. The conclusion based on the positive instances appears to be strengthened by the negative instances. The *Method of Double Agreement* is wrongly employed here. The positive and negative instances are not exhaustive. There are some authors, statesmen, and big merchants, who have good hand-

writing. There are some petty clerks who have poor hand-writing. Moreover, clerks have ample opportunities for hand-writing. But statesmen and big merchants have a little scope for hand-writing, though most authors have some practice in the art. These relevant circumstances are not observed. Hence the conclusion is vitiated by *Non-observation* of relevant circumstances.

(2) 'It was long known that light is a detriment to the preservation of milk. But until recently it was not known which of the rays did the mischief. Dr. P. put sterilized and unsterilized milk in uncoloured glass bottles, in red glass bottles, in orange coloured glass bottles, and in glass bottles of the other colours. He then placed all the bottles in the light for a whole day. It was found, at the end of the day, that both kinds of milk in the red glass bottles were fresh, even the unsterilized milk being good still for many hours. But the milk in all other bottles had *turned.* Red rays, therefore, appear to be beneficial to the preservation of milk.' (*Wolf*).

Here we observe a number of positive instances. Sterilized and unsterilized milk is kept in red glass bottles exposed to the light for a whole day, and the milk is found to be fresh at the end of the day. Therefore, red rays appear to be beneficial to the preservation of milk. This conclusion is strengthened by a number of negative instances. Sterilized and unsterilized milk is kept in uncoloured glass bottles, in orange-coloured glass bottles, and in glass bottles of the other colours exposed to the light for a whole day, and the milk is found to have 'turned' at the end of the day. Thus the *Method of Double Agreement* is rightly employed. The conclusion is certain. The irrelevant circumstances are sufficiently eliminated.

(3) A student keeps fit when the weather is fine and he can play football, but whenever it is wet and he is unable to take part in vigorous outdoor games, or go out for long walks, he suffers from indigestion. He, therefore, believes that rainy season is unhealthy.

Here we observe a number of positive instances and a number of negative instances. Whenever rainy season and want of physical exercise are present, ill-health is present, and whenever they are absent, ill-health is absent. Here the *Method of Double Agreement* is applied. Therefore, rainy season is a contributory cause or condition of ill-health. It cannot be regarded as the *whole* cause. Want of physical exercise is a material condition of ill-health.

(4) 'Darwin observed that many plots of land containing all of them plenty of earth-worms, although otherwise very different in character, became covered increasingly with vegetable mould, whereas, on the other hand, many plots of land not essentially unlike the former plots as a whole, but deficient in earth-worms, did not get covered with vegetable mould. He therefore concluded that the vegetable mould is due to the agency of earth-worms.' (*Wolf*).

The argument may be analysed in the above manner. The *Method of Double Agreement* is rightly applied here. The conclusion is certain.

5. The Method of Difference.

It is a method of Experiment. Here the other circumstances remaining the same, the introduction of an agent is followed by the appearance of a phenomenon, or the elimination of an agent is followed by the disappearance of a phenomenon. It is vitiated by the presence or absence of a hidden agent.

(1) 'A fresh water crayfish, having its antennules (small feelers) intact, retreats from strong odours, while another, bereft of them, does not react to strong odours at all. Therefore, the antennules are the organs of smell.' (*Wolf*).

There are two instances here, one positive and the other negative. When the antennules are present, reaction to strong odours is present. And when the antennules are absent, reaction to strong odours is absent. All other circumstances are perfectly identical. Therefore, the antennules are the organs of smell.

The *Method of Difference* is rightly applied here. The conclusion is certain.

(2) 'In 1861 there died at the Bicetre a patient who for 20 years had been without the power of speech, apparently through loss of memory of words. An autopsy revealed that a certain convolution of the left frontal lobe of his cerebrum had been totally destroyed by disease, the remainder of the brain being intact. Broca held that this case pointed strongly to a localization of the memory of words in a definite area of the brain.' (*Wolf*).

The argument may be analysed in the above manner. All other circumstances remaining the same, a certain region of the cerebrum is totally destroyed and the loss of memory of words expressed in the loss of the power of speech follows. Therefore, the former is the cause of the latter. The *Method of Difference* is rightly applied here. The conclusion is certain.

(3) 'Sachs found that when light was excluded from a plant, although all other conditions remained the same, no starch was formed ; but when the plant was exposed to light again, there was a renewed formation of starch. Similarly, when certain portions of the leaves of an illuminated plant were covered with black paper, no starch was formed in those portions. Sachs concluded that starch is formed in plants by the decomposition of carbon dioxide gas in chlorophyl under the influence of light.' (*Wolf*).

The conclusion 'Starch is formed in plants under the influence of light' is based on two experiments. All other conditions remaining the same, when light was excluded, no starch was formed in a plant, and when light was re-introduced, starch was formed again in it. Hence the *Method of Difference* is correctly applied here.

The conclusion is strengthened by another experiment. Light was excluded from certain portions of the leaves of an illuminated plant by covering them with black paper, and no starch was formed in those portions. Here also the *Method of Difference* is rightly applied. The conclusion is certain.

(4) 'Green colour is found only in the surface region of plants. If one cuts across a living twig into a cactus body, the green colour will be seen only in the outer part of the section. Hence the green colour of plants holds some necessary relation to light.'

There are only two instances here, one positive and the other negative. The outer part and the interior part of a twig resemble in all respects except one. The outer part is exposed to light and is green. The interior part is not exposed to light and is not green. All other circumstances remaining the same, exposure to light is eliminated and green colour also disappears. Hence the *Method of Difference* is rightly employed here, and the conclusion is valid.

6. The Method of Concomitant Variations.

This Method is vitiated by (i) mistaking qualitative variations for quantitative variations and applying it to the former; (ii) applying it beyond the limits of observation, and (iii) failure to distinguish between cause and effect and co-effects of the same cause. In cases of observation, it is vitiated by Plurality of Causes.

(1) 'The air must be the cause of sound: for (*i*) when you ring a bell in a vacuum there is no sound; (*ii*) if a little air is allowed to enter into the vacuum, a faint sound is heard; and (*iii*) as more air is allowed to enter the sound increases.' (*Latta and Macbeath*).

Where there is the air, there is sound. Where there is no air, there is no sound. Therefore the air must be the cause of sound. The conditions can be satisfied by an experiment only. The *Method of Difference* is rightly applied here. The conclusion is confirmed by another method.

The more the air, the louder the sound. So the air is the cause of sound. The *Method of Concomitant Varitations* is rightly applied here. The conclusion is certain.

(2) 'There is no such thing as colour really inhering in material bodies; it is altogether in the light. For colours are more or less vivid in proportion to the light; and if there be no light, then there are no colours perceived.' (*Wolf*).

The greater the light, the more vivid the colours. The less the light, the less vivid the colours. Therefore colours exist in light. The *Method of Concomitant Variations* is applied here. But the conclusion justified by it is that perceptions of light and colour are causally connected with each other. It does not warrant the conclusion that light is the cause of colour and there is no colour inhering in material bodies.

Again, if there be no light, no colours can be perceived. Therefore light is the cause of the perception of colours. The conclusion drawn already according to the Method of Concomitant Variations is strengthened by the *Method of Difference.* But the conclusion justified by the evidence is that light is a *condition* of the perception of colour.

(3) 'The effect of green feed on the colour of the yolk of eggs has been studied recently by Professor Wheeler of New York. Four lots of hens were fed *alike*, except that no hay or green feed was given to one lot, while the other three lots had varying amounts of clover hay alternating with green alfalfa. The depth of colour of the yolk varied in the different lots, and, roughly speaking, was directly proportional to the amount of the clover and alfalfa on which the laying hens were fed. Apparently the colouring matter present in the green feed affects the yellow colouring matter of the yolks of eggs.' (*Wolf*).

The conclusion is that 'the amount of green feed given to the hens determines the colour of the yolk of their eggs.' The three lots of hens which had green feed all laid eggs with coloured yolks. These may be regarded as one positive group. The lot of hens which had no green feed laid eggs the yolks of which had no distinct colour. This lot may be regarded as one negative group. The *Method of Difference* is rightly applied here. All other circumstances remaining the same, the introduction of an agent is followed by the appearance of a consequent. In other words, the green feed is followed by vivid colour in the yolks of eggs. Therefore the green feed is the cause of vivid colour in the yolks of eggs.

This conclusion is strengthened by the *Method of Concomitant Variations.* Among the three positive lots of hens it is found that as the amount of green feed given to the hens increased or decreased, the depth of colour of the yolks increased or decreased concomitantly,—all other circumstances remaining the same. Thus the Method of Concomitant Variations is rightly applied.[1]

(4) 'It has been observed that the simpler the type of an animal's nervous system the fewer and mechanical are the activities of which the animal is capable; while, on the other hand, the more elaborate the nervous system the more complex and adaptable are its reactions. And, since intelligence generally shows itself by great adaptability to surroundings, it would appear that intelligence depends on the nervous system.' (*Wolf*).

The greater the complexity of the nervous system, the greater the complexity and adaptability of reactions to the surroundings. The simpler the nervous system, the fewer and more mechanical the reactions. Intelligence is manifested in great adaptability to surroundings. Therefore intelligence depends upon the complexity of the nervous system. The *Method of Concomitant Variations* is rightly employed here. It shows that the two phenomena are causally connected. But it cannot determine the nature of the causal connection.

7. The Method of Residues.

The Method is vitiated by (i) inaccurate observation of the positive instance, and (ii) inaccurate deduction of the joint effect from the co-operation of causes known by previous inductions in the negative instance. It is a quantitative method. It yields a certain result if exact estimates can be obtained by experiments. When it is based on observation, it cannot yield a certain conclusion.

(1) 'When heat is applied to a thermometer, the mercury first falls a little, then rises. Since only the rise is caused by

1 *Text-Book of Logic*, 1930, pp. 378-79.

the expansion of mercury, the fall must be due to some other cause, *i. e.*, the expansion of the glass tube by the heat.'

Here there are two instances, one positive and the other negative. When heat is applied to a thermometer, the mercury first falls a little then rises. This is the positive instance. It is known that the rise in the column of mercury is due to the expansion of mercury under the influence of heat. This is the negative instance. Therefore, the residual phenomenon, *viz.*, the fall, must be due to the remaining antecedent, *viz.*, the expansion of the glass tube under the influence of heat. The *Method of Residues* is rightly applied. The conclusion is certain.

(2) If a spring tide due to the attraction of the sun and the moon is twelve feet at a certain place, and we know that an ordinary tide. due to the moon alone is eleven feet, we conclude that the sun's attraction causes a rise of one foot.

The argument may be analysed in the above manner. The *Method of Residues* is rightly applied here. The conclusion is certain, if we are sure of the truth of the premises.

(3) 'Pasteur filled part of a bottle with wine, and sealed the bottle hermetically. Presently the wine changed into vinegar. Pasteur then submerged the bottle well under water and then withdrew the cork. The water rushed into the bottle and filled just one fifth of the space originally occupied by air. Now, air is composed of one part of oxygen to four parts of nitrogen. Moreover, the gas left in the bottle had all the properties of nitrogen. Pasteur therefore concluded that during the process of acetification oxygen is taken from the air.' (*Wolf*).

We observe two instances here, one positive and the other negative. The positive instance is obtained from observation. The negative instance is obtained by deduction from previous inductions. It is known already that air is composed of four parts of nitrogen and one part of oxygen. As soon as the bottle is uncorked under water, water rushes into it and occupies one-fifth of the space originally occupied by air. The gas that is left in the bottle is found to be nitrogen. Therefore, the residue

of the air originally occupying the bottle and taken from the air by the wine during acetification is oxygen. Here the *Method of Residues* is rightly employed. The conclusion is certain.

(4) 'When air is confined with moistened iron filings in a closed vessel over water, the iron filings rust, and the volume of air is diminished. Moreover, the air which remains does not support flame or life. This shows that iron absorbs part of the air, and indeed that part of the air which supports fire and life.' (*Wolf*).

It is known already that air consists of nitrogen and oxygen. Oxygen supports combustion and life, but nitrogen does not. When the iron filings rust in contact with air, and the volume of air is diminished, and the residual gas is found not to be oxygen, it is proved that the iron filings have absorbed oxygen of air and combined into rust. The *Method of Residues* is rightly applied here.

EXERCISES

Test the following arguments:—

1. 'In all unhealthy countries the greatest risk of fever is run by sleeping on shore. Is this owing to the state of the body during sleep, or to a greater abundance of miasma at such times? It appears certain that those who stay on board a vessel, though anchored at only a short distance from the coast, generally suffer less than those actually on shore.' (*Darwin*).

2. 'If an active leaf be submerged in water contained in a glass vessel and exposed to the light, bubbles may be seen coming from the surface of the leaf and rising through the water. (The water is only a device by which the bubbles of gas may be seen). If the leaf is very active, the bubbles are numerous. If the light is diminished gradually, the bubbles become fewer, and eventually cease altogether. If next light is increased again gradually, the bubbles reappear, and become more and more numerous as the light increases. This shows that the activity of the leaf is dependent upon light.' (*Wolf*).

3. Linnets when shut up and educated with singing larks, the skylark, the woodlark, or titlark—will adhere entirely to the songs of these larks, instead of the natural song of the linnets. Hence we may infer that linnets learn to sing by imitation.

4. The great famine in Ireland began in 1845 and reached its climax in 1848. During this time agrarian crime increased very rapidly until in 1848 it was more than three times as great as in 1845. After this time it decreased with return of better crops, and in 1851 was only 50 per cent. more than in 1845. It is evident from this that a close relation of cause and effect exists between famine and agrarian crime.

5. Plants that grow in light develop green colour in their leaves Plants that grow in the dark do not develop it. Even when leaves have developed the green colour, they lose it if deprived of light. Light is, therefore, the cause of the green colour of plants.

6. Dogs are liable to a disease called rabies. If dogs infected with rabies bite healthy persons, they develop hydrophobia. The specific virus of the disease is found in their saliva, salivary glands, and spinal cord. Pasteur inoculated healthy dogs and rabbits with an emulsion of such a spinal cord, and reproduced rabies in them. He prepared such emulsions of varying intensity. He inoculated some dogs infected with rabies with emulsion of increasing strength, and they survived, which proved fatal in other dogs. Then Pasteur inoculated human beings suffering from hydrophobia with the virus of increasing intensity. The rate of mortality among patients so treated was much lower than among those not so treated.

7. 'Schwabe discovered that sun-spots reached a maximum once in approximately ten years. Lamont found that magnetic storms showed a periodicity of about ten years. Sabine discovered independently that magnetic disturbances reached a maximum of violence and frequency at intervals of about ten years. He noted, moreover, the coincidence between the period of magnetic storms and that of sun-spots ; and showed that, according to the available data, the two cycles of change agree in duration and phase, maximum corresponding to maximum, and minimum to minimum. He

concluded that there was some connection between them, though he could not explain the nature of the connection.' (*Wolf*).

8. A ship sails on a Friday and is shipwrecked. Some passengers blame their folly in starting on an unlucky day.

9. In a mining town in the western states of America, the boast was made that except through accident or foul play, there had been no death in the past three years. It was claimed there fore that the town was exceptionally healthy.

10. 'I remember as a boy lying on the grass on a summer's day looking up into the sky. I saw, as I thought, a very big bird very high up in the air. In another moment I found that I was mistaken and that what had really happened was that a very small fly had passed quite close to the eye.' (*Stock*).

11. 'Italy is a Catholic country, and abounds in beggars; France is also a Catholic country, and therefore abounds in beggars.' (*Jevons*).

12. Lord Curzon, arguing for the continued existence of a hereditary Chamber, said: "The hereditary principle is established in every branch and aspect of our national life. We have hereditary bankers, lawyers, and even hereditary cotton-spinners. Why should it be a blot and offence when applied to the House of Lords?" (*Creighton*).

13. 'Tyndall showed that in an hermetically closed box in which the air was entirely free from all floating particles, putrescible liquids in test-tubes, previously sterilized, could be exposed indefinitely without spoiling. But after admitting the outside air, even for an instant, the liquids in the test-tubes became spoiled within a few days and full of micro-organisms'. (*Wolf*).

14. 'After Franklin had investigated the nature of electricity for some time, he began to consider how many of the effects of thunder and lightning were the same as those produced by electricity. Lightning travels in a zigzag line, and so does an electric spark; electricity sets things on fire, so does lightning; electricity melts metals, so does lightning. Animals can be killed by both, and both cause blindness. Pointed bodies attract the

electric spark, and in the same way lightning strikes spires, and trees, and mountain tops. Is it not likely then that lightning is nothing more than electricity passing from one cloud to another, just as an electric spark passes from one substance to another?' (*Creighton*).

15. 'What would our ancestors say to this, Sir? How does this measure tally with their institutions? How does it agree with their experience? Are we to put the wisdom of yesterday in competition with the wisdom of centuries? Is beardless youth to show no respect for the decisions of mature age?' (*Sydney Smith*).

16. 'The Nile by overflowing its banks enriches the neighbouring country; therefore the Po by overflowing its banks will enrich the neighbouring country'. (*Jevons*).

17. All the great empires that have ever existed have lost their supreme position. Hence no great empire in the future will maintain its supremacy.

18. The wearing of stiff collars, neckties, and tall hats, and the carrying of umbrellas enlarge the chest, prolong life, and confer comparative immunity from disease; for statistics show that the classes which use these articles are bigger, healthier, and live longer than the poorer classes which cannot afford to purchase such things.

19. If on a clear night a sheet or other covering be stretched a foot or two above the earth, so as to screen the ground below from the open sky, dew will be found on the grass around the screen but not beneath it. The open sky therefore must be an indispensable antecedent of dew.

20. The retention of an idea in memory becomes more tenacious with the frequency of its repetition and the increased attention we pay to it. The retention of an idea in memory depends therefore on attention and repetition.

THE END.